VISIT…

Chapter 7

Synthetic Lubricants*

Judicious application of properly formulated synthetic lubricants can benefit a wide spectrum of process machinery. This informed usage is very likely to drive down overall maintenance and downtime expenditures and can markedly improve plant profitability.

However, although synthetic lubricants have gained considerable acceptance in many forward-looking process plants world-wide, there are still misconceptions which impede the even wider acceptance many of these fluids so richly deserve. One of the erroneous understandings is that for a synthetic lubricant costing $15.00 per gallon to be justified, the drainage or replacement interval should be five times that of a mineral oil costing $3.00 per gallon. This reasoning does not take into account such savings as labor, energy, downtime avoidance, disposal of spent lubricants and equipment life extension.

A serious engineer or maintenance professional would be well advised to take a closer look at the profusion of authenticated case histories covering the widest possible spectrum of machinery. One major chemical company documented yearly savings of $70,200 for 36 right-angle gear units driving cooling fans in a process plant. One refinery saved $120,000 per year for Ljungstrom furnace air preheaters and greatly extended mean-time-between-repairs (MTBR) for Sundyne high speed gear units. On these Sundyne units, strangely enough, hundreds of users continue to use automatic transmission fluid (ATF). In this particular service, ATF is demonstrably inferior to properly formulated synthetic oils.

FORMULATIONS

The most knowledgeable formulators use a polyalphaolefin/diester blend. Additives are more readily soluble in diesters than in PAO. Therefore, PAO/diester blends are stable over a very wide temperature range. These superior synthetic base oils must be blended with additives to obtain the high level of performance required.

It should be emphasized that the additives represent by far the most important ingredients of properly formulated, high performance synthetic lubricants. Often, additives used in synthetic oil formulations are the same conventional additives used to formulate mineral oils, resulting in only marginal performance improvements. Truly significant

*Sources: Bloch, H.P., and Pate, A.R. (Jr.); "Consider Synthetic Lubricants for Process Machinery," *Hydrocarbon Processing*, January, 1995. Also: Bloch, H.P., and Williams, John B., "High Film Strength Synthetic Lubricants Find Application in Process Plant Machinery," *P/PM Technology*, April, 1994.

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performance improvements are obtained only when superior synthetic base oils are blended with superior synthetic additive technology.

The various proven PAO/diester blends contain synergistic additive systems identified with proprietary trade names (Synerlec, etc.). The synergism obtained in a competent additive blend combines all of the desirable performance properties plus the ability to ionically bond to bearing metals to reduce the coefficient of friction and greatly increase the oil film strength. The resulting tough, tenacious, slippery synthetic film makes equipment last longer, run cooler, quieter, smoother and more efficiently. Synergistic additive systems, in service, "micro-polish" bearing surfaces reducing bearing vibration, reducing friction and minimizing energy consumption. This gets us into the topic of "how and why."

How and Why

The most valuable synthetic lubricant types excel in high film strength and oxidation stability. However, while there are many high film strength oils on the market, these may not be appropriate for some process machine applications. High film strength oils based on extreme pressure (EP) technology and intended for gear lubrication may typically incorporate additives such as sulfur, phosphorus and chlorine which are corrosive at high temperatures and/or in moist environments. Sensitive to this fact, a reputable lubricant manufacturer thus would not offer an EP industrial oil with corrosive additives as a bearing lubricant for pumps, air compressors, steam turbines, high speed gear reducers and similar machinery.

At least one U.S. manufacturer of synthetic lubricants can lay claim to having pioneered the development of noncorrosive high film strength industrial oils with outstanding water separation properties. Although such oils may not be critically important to the operating success of vast numbers of pumps, air compressors and turbines, which quite obviously have been running without high film strength oils for years, there are compelling reasons to look into the merits of superior lubricants. There is a considerable body of thoroughly evaluated evidence that *properly formulated* synthetic lubricants based on diesters, PAO, or a combination of these base stocks will result in significantly reduced bearing and gear operating temperatures.

Our advice to the serious maintenance professional is to ascertain the requirements needed for maximum performance in specific equipment. Look at the published specifications of various oils and determine their relative merits for the intended service. Make an informed decision based on the facts and then monitor the field performance. Chances are you will greatly increase equipment reliability by picking the *right* synthetic lube.

ORIGIN OF SYNTHETIC LUBES

Synthetic-based fluids, used in the production of synthetic lubricants, are manufactured from specific chemical compounds that are usually petroleum derived. The base fluids are made by chemically combining (synthesizing) various low molecular weight compounds to obtain a product with the desired properties. Thus, unlike petroleum oils

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which are complex mixtures of naturally occurring hydrocarbons, synthetic base fluids are man-made and have a controlled molecular structure with predictable properties. These are "generalized" in Table 7-1.

There is no typical synthetic lubricant. The major classes are as different from each other as they are from petroleum lubricants. Synthesized base fluids are classified as follows:

1. Synthesized hydrocarbons (polyalphaolefins)
2. Organic esters (diesters and polyol esters)
3. Polyglycols
4. Phosphate esters
5. Silicones
6. Blends.

The first four base fluids account for more than 90% of the synthetic fluids used worldwide. The first three contain only atoms of carbon, hydrogen and oxygen. The first two are of greatest interest to machinery engineers in modern process plants.

EXAMINING SYNTHETIC LUBES

Understanding the principal features and attributes of the six base fluids will place the potential user in a position to prescreen applicable synthetics and to question suppliers whose offer or proposal seems at odds with these performance stipulations.

Synthetic Hydrocarbon Fluids

Synthetic hydrocarbon fluids (SHF), such as those with a polyalphaolefin (PAO) base, provide many of the best lubricating properties of petroleum oils but do not have their drawbacks. (Even the best petroleum oils contain waxes that gel at low temperatures and constituents that vaporize or readily oxidize at high temperatures.) The SHF base fluids are made by chemically combining various low molecular weight linear alpha olefins to obtain a product with the desired physical properties. They are similar to cross-branched paraffinic petroleum oils because they consist of fully saturated carbon and hydrogen.

These man-made fluids have a controlled molecular structure with predictable properties. They are available in several viscosity grades and range from products for low temperature applications to those recommended for high temperature uses. They are favored for their hydrolytic stability, chemical stability and low toxicity.

Organic Esters

Organic esters are either dibasic acid or polyol types. Dibasic acids have shearstable viscosity over a wide temperature range (-90°F to 400°F), high film strength, good metal wetting properties and low vapor pressure at elevated temperatures. They easily accept additives, enhancing their use in many commercial applications and especially as

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*Table 7-1. Generalized properties of synthetic hydrocarbon lubes**

	Mineral Oils	Polyisobutenes	Polyalpha-olefins	Alkylated Aromatics	Polyalkylene Glycols	Perfluoroalkyl Ethers	Polyphenylethers	Dicarboxylic Acid Esters	Neopentyl Polyesters	Trialkyl Phosphate Esters	Triakyl Phosphate Esters	Silicone Oils
Viscosity Temperature Behavior (VI)	Moderate	Poor	Very Good	Moderate	Very Good	Moderate	Poor	Very Good	Very Good	Poor	Excellent	Excellent
Low Temperature Behavior (Pourpoint)	Poor	Moderate	Excellent	Good	Good	Good	Poor	Excellent	Very Good	Moderate	Excellent	Excellent
Liquid Range	Moderate	Poor	Very Good	Good	Good	Excellent	Poor	Very Good	Very Good	Very Good	Good	Excellent
Oxidation Stability (Aging)	Moderate	Moderate	Very Good	Moderate	Good	Excellent	Very Good Good	Very Good/	Very Good	Very Good	Moderate	Very Good
Thermal Stability	Moderate	Moderate	Moderate	Moderate	Good	Excellent	Excellent	Good	Very Good	Very Good	Good	Very Good
Evaporation Loss, Volatility	Moderate	Moderate	Very Good	Good	Good	Excellent	Good	Excellent	Excellent	Very Good/	Very Good/	Very Good/
Fire Resistance, Flash Temperature	Poor	Poor	Poor	Poor	Moderate	Excellent	Moderate	Moderate	Moderate Very Good/	Excellent/ Very Good/	Excellent/	Good
Hydrolytic Stability	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Excellent	Moderate	Moderate	Moderate	Good	Good
Corrosion Protection Properties	Excellent	Excellent	Excellent	Excellent	Good	Poor	Moderate	Moderate	Moderate	Moderate	Moderate	Good
Seal Material Compatibility	Good	Good	Very Good/	Good	Good	Excellent	Good	Moderate	Moderate	Poor	Poor	Good
Paint and Lacquer Compatibility	Excellent	Excellent	Excellent	Excellent	Moderate	Very Good/	Moderate	Moderate	Moderate	Poor	Poor	Good
Miscibility with Mineral Oil	—	Excellent	Excellent	Excellent	Poor	Poor	Good	Very Good/	Very Good/	Moderate	Moderate	Poor
Solubility of Additives	Excellent	Excellent	Very Good/	Excellent	Moderate	Poor	Very Good/	Very Good/	Very Good/	Excellent	Excellent	Poor
Lubricating Properties, Load Carrying Capacity	Good	Good	Good	Good	Very Good/	Excellent	Excellent	Very Good/	Very Good/	Excellent	Moderate	Poor
Toxicity	Good	Excellent	Excellent	Poor	Good	Excellent	Good	Good	Good Good	Very Good// Poor	Moderate/	Excellent
Biodegradability	Moderate	Poor	Good/ Moderate	Poor	Excellent Very Good/	Poor	Poor	Excellent Very Good/	Excellent Very Good/	Very Good/	Very Good/	Poor
Price Relation Against Mineral Oil	—	3-5	3-5	3-5	6-10	500	200-500	4-10	4-10	5-10	5-10	30-100

*Source: Technische Akademie Esslingen, Germany

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compressor lubricants.

Polyol esters have many of the performance advantages of dibasic acid esters and can be used at even higher temperatures. They are used principally in high-temperature chain lubricants, for industrial turbines and in some aviation applications.

Polyglycols

Polyglycols were one of the first synthetic lubricants developed. The polyglycols can be manufactured from either ethylene oxide, propylene oxide or a mixture of both. The propylene oxide polymers tend to be hydrocarbon soluble and water insoluble, while the ethylene oxide tends to be water soluble and hydrocarbon insoluble. In many applications, the physical properties of the finished product can be engineered by adjusting the ratio of ethylene oxide and propylene oxide in the final molecular structure.

Polyglycols have excellent viscosity and temperature properties and are used in applications from -40°F to 400°F and have low sludge-forming tendencies. A major application for polyglycol lubricants is in compressors that handle hydrocarbon gases. This is due to the nonhydrocarbon-diluting properties inherent in polyglycols. The polyglycols' affinity for water results in poor water separability.

Phosphate Esters

Phosphate esters are organic esters that, when used with carefully selected additives, provide a group of synthetic fluids that can be used where fire resistance is required. Even when ignited, the phosphate esters will continue to burn only if severe conditions required for ignition are maintained. Some phosphate esters are less stable in the presence of moisture and heat. The products of the resulting degradation are corrosive and will attack paints and rubbers. The poor viscosity index (VI) limits the operating temperature range for any given phosphate ester product.

Silicones have been in existence for many years and offer a number of advantages as lubricants. Silicones have good viscosity versus temperature performance, excellent heat resistance, oxidative stability and low volatility. Silicones are chemically inert and have good elastomer compatibility. Poor metal-to-metal lubricating properties and high cost limit their use to specialized applications where their unique properties and high performance can be justified.

Blends of the Synthetic Lubricants

Blends of the synthetic lubricants with each other or with petroleum lubricants have significant synergistic results. In fact, many of the synthetic lubricants being sold consist of a blend of two or more base materials to enhance the properties of the finished product.

Synthetic lubricants have been steadily gaining industrial acceptance since the late 1950s. In many applications today, they are the specified lubricant of the compressor manufacturer. This is especially true in rotary screw and rotary vane air compressors.

While the greatest industrial acceptance has been with air compression, many other industrial applications can be economically justified. Synthetic lubricants are currently being used in compressors processing such diverse materials as ammonia, hydrogen,

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hydrocarbon gases, natural gas, hydrogen chloride, nitrogen and numerous others.

Synthetic lubricants are not limited to compressors but are used in gear boxes, vacuum pumps, valves, diaphragm pumps and hydraulic systems. Synthetic lubricants are being used in applications that need more efficient, safe lubrication or where the environmental conditions preclude the use of traditional petroleum products.

PROPERTIES AND ADVANTAGES

Synthetic lubricant fluids provide many of the best lubricating properties of mineral oils but do not have their drawbacks. In fact, synthetics have these advantages over comparable petroleum-based lubricants:

- Improved thermal and oxidative stability
- More desirable viscosity-temperature characteristics
- Superior volatility characteristics
- Preferred frictional properties
- Better heat transfer properties
- Higher flash point and auto-ignition temperatures.

Experience clearly shows that these advantages result in the following economic benefits:

- Increased service life of the lubricant (typically four to eight times longer than petroleum lubricants)
- Less lubricant consumption due to its low volatility
- Reduced deposit formation as a result of good high-temperature oxidation stability
- Increased wear protection resulting in less frequent maintenance
- Reduced energy consumption because of increased lubricating efficiency
- Improved cold weather flow properties
- Reduced fire hazard resulting in lower insurance premiums
- Higher productivity, lower manufacturing costs and less downtime because machines run at higher speeds and loads with lower temperatures
- Longer machinery life because less wear results in more production during life of machine and tools.

Synthetic lubricant base stocks, while possessing many of the attributes needed for good lubrication, require fortification with additives relative to their intended use. An experienced formulator takes into consideration a range of requirements:

Dispersion of Contaminants

It is important to keep internally and externally generated oil-insoluble deposit-forming particles suspended in the oil. This mechanism reduces the tendency of deposits,

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which lower operating efficiency, to form in critical areas of machinery. Additives that impart dispersing characteristics are called "dispersants" and "detergents." A dispersant is distinguished from a detergent in that it is nonmetallic, does not leave an ash when the oil is burned and can keep larger quantities of contaminants in suspension.

Protecting the Metal Surface from Rust and Corrosion

Humidity (water) type rust and acid type corrosion must be inhibited for long surface life. An oil film itself is helpful but this film is easily replaced at the metal surface by water droplets and acidic constituents. Additives that have an affinity for a metal surface, more so than water or acids, are used in oils to prevent rust and corrosion and are generally referred to as simply "rust inhibitors."

Oxidative Stability

Oils tend to thicken in use, especially under conditions where they are exposed to the atmosphere or where oxygen is present. This phenomenon is chemically termed "oxidation."

Oxygen reacts with the oil molecule initiating a chain reaction that makes the molecule larger, thereby decreasing fluidity. Conditions that assist the oxidation process are heat, oxidation catalyzing chemicals, aeration and perhaps other mechanisms that allow the oxygen to easily attach itself. Additives that retard the oxidation process are termed "oxidation inhibitors."

Wear Prevention

Inevitably the metal surfaces being lubricated come in contact. Whenever the speed of relative motion is low enough, the oil film does not stay in place. This can also happen if the loading on either or both surfaces is such that the oil film tends to be squeezed out. When moving metal surfaces come in contact, certain wear particles are dislodged and wear begins. Additives that form a protective film on the surfaces are called "anti-wear agents."

Viscosity Index Improvers

Viscosity index improvers function to improve viscosity/temperature relationships, that is, to reduce the effect of temperature on viscosity change.

Foam Suppressants

Foam suppressants allow entrained air bubbles to collapse more readily when they reach the surface of the oil. They function by reducing surface tension of the oil film.

Oiliness Additives

Oiliness additives are materials that reduce the oil friction coefficient.

Surfactants

Surfactants improve the ability of the oil to "wet" the metal surface.

Alkalinity Agents

Alkalinity agents impart alkalinity or basicity to oils where this is a desirable feature.

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Tackiness Agents

Tackiness agents impart stringiness or tackiness to an oil. This is sometimes desirable to improve adhesive qualities.

Obviously then, the lubricant supplier or formulator has to choose from a number of options. There are technical considerations to weigh and compromises to make. Close cooperation between supplier and user is helpful; formulator experience and integrity is essential.

CASE HISTORIES

The following are highlights from the many successful case histories of the late 1980's and 1990's.

Circulating Oil System for Furnace Air Preheaters

Several major refineries in the U.S. and Europe had experienced frequent bearing failures on these slow-rotating heat exchangers while operating on the manufacturer-recommended mineral oil. With bearing housings typically reaching temperatures around 270°F, the cooled and filtered mineral oil would still overheat to the point of coking. Bearing failures after six months of operation were the norm. After changing to a properly formulated synthetic, a lubricant with superior high-temperature capabilities and low volatility, bearing lives were extended to several years. As was mentioned in our introductory paragraph, one refinery alone has documented savings of approximately $120,000 per year since changing lubricants.

Right-angle Gear Drives for Fin Fan Coolers

A European facility achieved a disappointing mean-time-between-failures (MTBF) of only 36 months on 36 hypoid gear sets in a difficult to reach, elevated area. In fact, using mineral oil (ISO VG 160), a drain interval of six months was necessary to obtain this MTBF. Each oil change required 12 man-hours and temporary scaffolding at a cost of $1,000. Change-over to an appropriate synthetic, i.e., a synthetic with optimized temperature stabilizers, wear reducers and oxidation inhibitors, has allowed drain intervals to be increased to two years while obtaining a simultaneous increase in equipment MTBF. Detailed calculations showed a net benefit of $1,950 per year per gear set. Combined yearly savings: $70,200 with no credit taken for power reduction or avoided production curtailments.

Plant-wide Oil Mist Systems.

An oil mist lubrication system at a Southeast Texas chemical plant experienced an unscheduled shutdown as a result of cold weather. Twenty-seven mist reclassifiers in this system were affected. These reclassifiers provided lubrication to several fin fans, two electric motors and the rolling element bearings in 14 centrifugal pumps. Wax plugging of the mist reclassifiers brought on by the cold weather caused the unexpected shutdown. As a result, several bearings failed because of lubricant starvation. An ISO VG 68 grade conventional mineral oil was the source of the wax.

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The oil mist system had to be isolated and blown out to avoid further bearing failures. In addition to the downtime costs, significant labor and hardware costs were required to restore the unit to normal operation.

For this reason, a synthetic wax-free lubricant replaced the mineral oil. Neither the oil feed rate nor the air-to-oil ratio required adjusting after switching to the synthetic.

Since converting years ago to a diester-based oil mist system, the following has resulted:

- No cold weather plugging of the mist reclassifiers has been experienced.
- No lubricant incompatibility has been detected with other components of the oil mist system.
- The synthetic lubricant is providing proper bearing wear protection as evidenced by no increase in required maintenance for pumps, fans or motors served by the oil mist system.
- Downtime, labor and hardware replacement costs attributed to cold weather operational problems have been eliminated.
- Savings in contractor and plant manpower used to clean the reclassifiers equaled $25,100 per year.
- Two failures of pumps and motors were assumed to be prevented via use of wax-free lubricant. The savings equaled $7,000 per year.

Total net credit has been $49,375 per year. This does not include any process losses associated with equipment outages.

Pulverizing Mills in Coal-fired Generating Plant.

A large coal-fired power generating station in the southwestern U.S. was having lubrication problems with their coal pulverizing mill. The equipment, a bowl mill pulverizer, was experiencing the following problems lubricating the gears that drive the mill:

- The lubricant was losing viscosity and had to be changed every four to six months.
- Air entrainment in the lubricant was causing cavitation in the pumps that circulated the lubricant.
- The gears were experiencing an unacceptable level of wear as measured by a metals analysis on the lubricant.
- On very cold mornings, the lubricant was so viscous it had to be heated before the unit could be put in service.
- The petroleum-based lubricant's initial viscosity varied significantly.

After evaluating the options, it was decided that a synthetic-based lubricant offered the best solution. In cooperation with a major synthetic lubricant manufacturer, they decided a synthetic hydrocarbon base stock with the proper additive package would be the

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best choice. Additive package concentrations were evaluated in a number of bowl mills simultaneously to establish the optimum level and composition. Figure 7-1 shows the dramatic effect on metal gear wear accomplished over a 1,000-hour trial period.

The synthetic hydrocarbon base stock has proven to be extremely shear resistant. One particular bowl mill has been closely monitored during 54 months of operation (Figure 7-2) to establish viscosity stability. The data represent only operating hours, not total time elapsed, since the unit is not operated continuously. The performance has been excellent and lubricant life has exceeded 60 months.

The synthetic hydrocarbon lubricant was compared to two petroleum-based lubricants supplied by major oil companies. The tests were run on three bowl mills that had recently been reworked and tested. All three bowl mills were fed the same amount of coal during the test period. All three gear oils were the same ISO 320 viscosity grade.

The average current draws were:

Product	**Amps**
Petroleum #1	70
Petroleum #2	75
Synthetic hydrocarbon gear oil	68

The lower amp difference shown by the synthetic hydrocarbon is the result of the lower coefficient of friction shown in Table 7-2.

Efficiency gains can be very sizeable and the resulting reduction in energy cost will often pay for the higher cost of synthetic lubricants within months. Table 7-3 shows a typical cost benefit analysis.

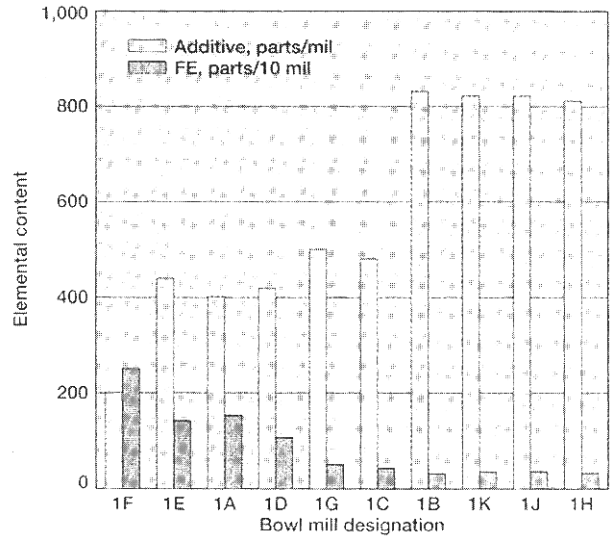

Figure 7-1. Bowl mill wear, 1,000 operating hours.

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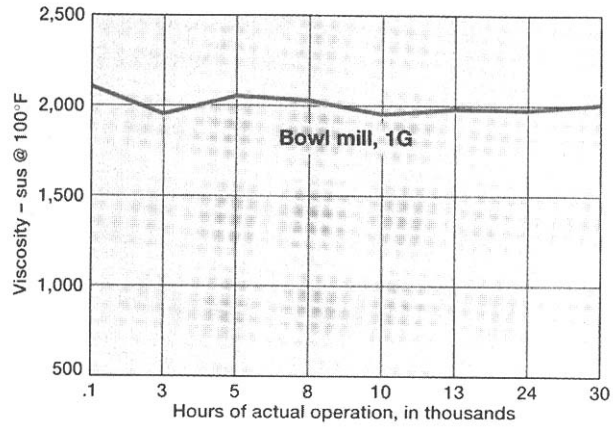

Figure 7-2. Viscosity stability of synthetic lubricant in bowl mill gear unit.

Table 7-2. Physical properties of ISO VG 320 gear oil.

	Petroleum	Synthetic hydrocarbon
Viscosity index	95	140
Thermal conductivity, Btu/hr/ft^2	0.071	0.085
Coefficient of friction	0.101	0.086
Pour point, °F	+5	–45

Table 7-3. Cost benefit analysis.

Synthetic Lubricant Price X Annual Volume	$ .....
Conventional Lubricant Price X Annual Volume	$ .....
NET COST DIFFERENCE (A)	$ .....
Credit For Enhanced Performance Of Synthetic Lube	
Extended Service Life	$ .....
Reduced Downtime	$ .....
Reduced Maintenance Cost	$ .....
Reduced Disposal Cost	$ .....
Reduced Energy Consumption	$ .....
Reduced Lubricant Inventory	$ .....
TOTAL OF CREDITS FOR SYNTHETICS LUBRICANT (B)	$ .....

Net Cost Difference (A)
– Total Credits (B)

Savings Through Use of Synthetic Lube (C)

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As demonstrated, the synthetic hydrocarbon gear oil has solved the original problems and provided additional benefits not anticipated. The switch to synthetic lubricants has clearly improved performance and achieved significant savings in operating costs, as shown in the following tabulation.

The extended drain interval provides savings in three areas:

1.	**Lubricant consumption cost savings:**		
	Petroleum oil cost per gal	$4.00	
	Petroleum oil changes per yr	2	
	Volume of gear box, gal	300	
	Petroleum oil cost per yr		
	($4.00/gal)(2 changes/yr)(300 gal/unit) =	$2,400	
	Synthetic oil cost per gal	$16.00	
	Synthetic oil changes per yr	0.2	
	Volume of gear box, gal	300	
	Synthetic oil cost per yr		
	($16.00/gal)(0.2 changes/yr)(300 gal/yr) =	$960	
	Annual savings on lubricant cost—	**$1,440**	**per unit**
2.	**Reduced maintenance cost savings**		
	Petroleum oil changes per yr	2	
	Maintenance cost per change	$500	
	Petroleum oil maintenance cost per yr		
	(2 changes/yr)($500/change) =	$1,000	
	Synthetic oil changes per yr	0.2	
	Maintenance cost per change	$500	
	Synthetic oil maintenance cost per yr		
	(0.2 changes/yr)($500/change)	$100	
	Annual savings in scheduled maintenance costs—	**$900**	
3.	**Lubricant disposal costs**		
	Petroleum oil used per yr, gal	600	
	Disposal cost per gal	$0.50	
	Cost of disposal	$300	
	Synthetic oil used per yr, gal	60	
	Disposal cost per gal	$0.50	
	Cost of disposal	$30	
	Annual savings in disposal cost per year—	**$270**	

The reduction in energy consumption also providles significant savings:

Average annual power cost using petroleum oil lubricant	$33,278
Average annual power cost using synthetic lubricant	$31,211
Annual savings in power consumption—	**$2,067**

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The total annual savings for all of the above categories amount to $4,677. In addition, savings in reduced wear and thus fewer repairs are certain to be realized. A forward-looking process plant needs to explore the many opportunities for often substantial cost savings that can be achieved by judiciously applying properly formulated synthetic lubricants.

Returning to the questions raised at the beginning of this chapter, Exxon offers the following comments by way of summation.

- **Should a synthetic lubricant be used?**

  Yes - if it is cost effective (increased productivity, extended lubricant life, etc.)

  Yes - if a conventional lubricant has not worked (problem solver).

  Yes - if it enhances safety or environmental aspects of an operation (higher flash & fire points, reduction of used lubricant requiring disposal).

  Yes - if it reduces risk (failure to change out systems, reduced chance of misapplication through lubricant consolidation).

- **What type of synthetic lubricant?**

  Key considerations here are temperature extremes in operation, material compatibility, equipment requirements and methods of its application.

- **What are the requirements for effective use of the selected synthetic lubricant?**

  In selecting a lubricant for demanding lubricant applications, there are generally one or two key imperatives that must be satisfied for things to work. Temperature extremes, lubricant service life, extreme loads, safety and environmental aspects usually are the key drivers. One or more of the demands will drive the selection of a synthetic for a specific application.

Synthetic lubricants offer significant advantages over conventional lubricants under demanding conditions. Their judicious use has enabled users to capture the following benefits:

— Increased Productivity
— Enhanced Equipment Performance
— Cost Savings
— Enhanced Safety
— Enhanced Environmental Aspects

The decision to use a synthetic lubricant and selection of the best lubricant is a process with a multitude of interrelationships. Equipment manufacturers, lubricant suppliers, maintenance and engineering staff, along with your own experience, can aid in the worthwhile process of improving plant efficiency through proper application of synthetic lubricants.

NOTE: Certain synthetic lubricants have been formulated for specific machinery applications. Refer to "compressors" for information on synthetics using polyalkylene

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glycols, "pulp and paper" for data on a full synthetic used in saw mills, and "gas engines" for more information on ESTOR Elite, a low-ash formulation, full synthetic, allowing extended drain intervals.

SYNTHETIC LUBRICANTS FOR EXTREME PRESSURE AND TEMPERATURE

Using Exxon's SPARTAN® and SYNESSTIC® synthetic lubricants as an example, we will attempt to illustrate the merits of properly formulated industrial lubricants.

SPARTAN® Synthetic EP excels because it flows freely in arctic temperatures that "freeze" conventional mineral oils stiff, Figure 7-3. It keeps its viscosity at steel-mill temperatures, Figure 7-4, that turn mineral oils to watery liquids. At the same time, it resists oxidation and demonstrates excellent volatility control at high temperatures—for long-term, reliable service.

Exxon's SPARTAN Synthetic EP gear oil consists of seven ISO grades (100-1000) suitable for a wide range of industrial gears that are subject to severe operating conditions, such as high pressures, shock loading or extremes in temperatures. The long service life of SPARTAN Synthetic EP makes it the best choice whenever routine lubricant changes are difficult or costly. SPARTAN Synthetic EP also is an excellent lubricant for both plain and rolling-contact bearings. These oils use high-quality polyalphaolefin basestocks and a proprietary additive package that together meet or exceed the tough AGMA, U.S. Steel (224), Cincinnati-Milacron, and David Brown specifications for EP gear oils. Refer to Table 7-4 for typical inspections.

Figure 7-3. The arctic demands free-flowing synthetic lubricants.

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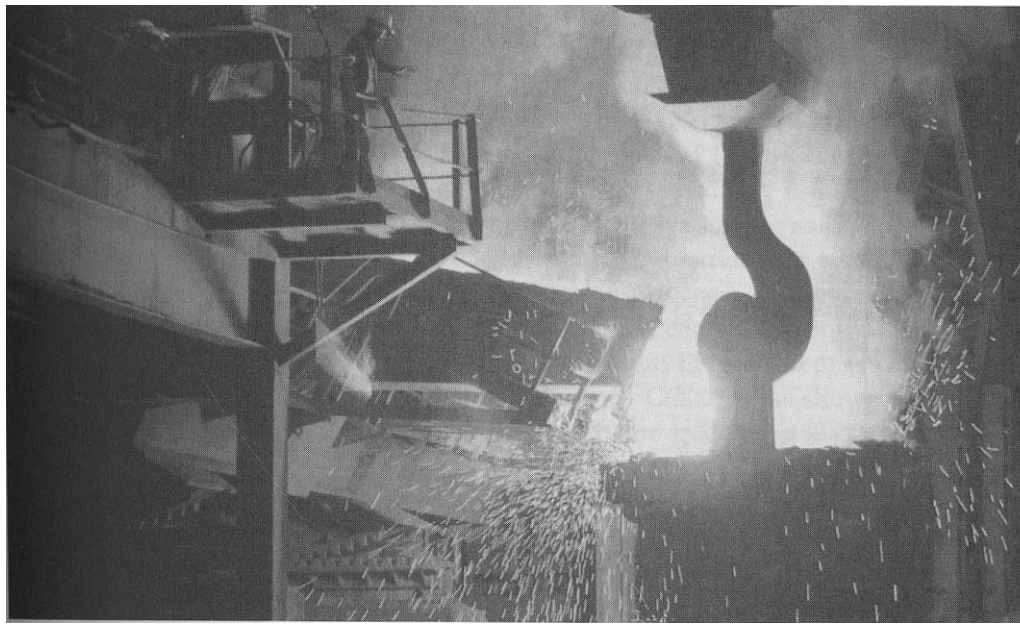

Figure 7-4. Steel mill temperature environment calls for synthetic lubricants.

Polyalphaolefins Make the Difference

To understand polyalphaolefins, it helps to start with paraffins.

Long-chain paraffin molecules of 20 to 40 carbon atoms have many excellent properties such as oxidation stability and viscosity that does not change drastically as temperature goes up or down. Most important, they lubricate well because they cling to metal surfaces and slide past each other easily.

In fact, these molecules might be ideal lubricants except for one serious drawback: Somewhere around room temperature (depending on the length of the chain), they crystallize and pack together like sticks of dry spaghetti. The result is a solid matrix of wax.

In petroleum-base lubricants, paraffins work because they occur naturally attached to cyclic structures that crystallize at lower temperatures. For the wax crystals that do form, added pour-point depressants help keep them from growing large enough to cause trouble.

But petroleum-base lubricants still have problems at temperature extremes: cyclic components get too thin at high temperatures and don't resist oxidation well—and even the best pour point depressants lose effectiveness at extremely low temperatures.

The ideal solution would be a paraffin that couldn't crystallize into wax. It should be exceptionally pure and uniform, with a narrow boiling range and virtually no variation in batch-to-batch properties.

That solution exists in the polyalphaolefin (PAO) basestocks used in superior synthetic EP industrial gear oils.

PAOs are specially synthesized branched paraffins with three to five 10-carbon chains united in a star-like structure. The shape virtually defies crystallization. The PAO

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Table 7-4. Typical inspections for SPARTAN Synthetic EP oils.

SPARTAN Synthetic EP Typical Inspections

The values shown here are representative of current production. Some are controlled by manufacturing specifications, while others are not. All of them may vary within modest ranges.

Grade	100	150	220	320	460	680	1000
AGMA number	3 EP	4 EP	5 EP	6 EP	7 EP	8 EP	8AEP
ISO viscosity grade	100	150	220	320	460	680	1000
Viscosity @ 40°C, cSt	106	151	220	327	427	680	989
@ 100°F, SUS	519	778	1149	1712	2241	3159	5154
@ 210°F, SUS	78	100	130	180	225	289	378
Viscosity index	151	150	151	162	167	160	154
API gravity	36.5	35.4	35.0	34.5	34.1	32.3	31.0
Demulsibility, ASTM D 2711							
Total free water, ml	86	85	85	84.5	84	85	8.4
% Water in oil	0.4	0.5	0.8	0.8	0.8	0.7	0.8
Emulsion, ml	0	0	0	0	0	0	0
Rust test, ASTM D 665A & B	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Four-ball EP test, ASTM D 2783							
Weld point, kg	250	250	250	250	250	250	250
Load wear index	54	53	46	46	47	47	47
Copper corrosion,							
ASTM D 130, rating	1-A	1-A	1-A		1-A	1-A	1-A
Foam test, ASTM D 892, ml							
Sequence I	Tr/0						
Sequence II	Tr/0						
Sequence III	Tr/0						
Timken OK load,							
ASTM D 2782, kg (lb)	36(80)	45+(100+)	45+(100+)	45+(100+)	45+(100+)	45+(100+)	45+(100+)
Flash point, °C (°F)	231 (448)	236 (457)	249 (480)	250 (482)	254 (490)	270 (518)	280(536)
Pour point, °C (°F)	-55 (-67)	-52 (-62)	-46 (-50)	-46 (-50)	-40 (-40)	-30 (-22)	-20 (-4)
FZG test, pass	12 stages	12 stages	12 stages	12 stages	12 stages	12 stages	12 stages
Oxidation tests							
ASTM D 2893	Pass	Pass	Pass	Pass	Pass	Pass	Pass
USS S-200[1]	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Mist test, ASTM D 3705							
% Stray mist	20	19	18	18	17	18	—
% Condensed mist	80	81	82	82	83	83	—

[1]Described in U.S. Steel 224 EP Gear Oil Specification.

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molecules in SPARTAN Synthetic EP resist freezing down to -40°C(-40°F) or lower, and they come close to the ideal lubricant in other ways too: they excel at maintaining viscosity, resisting oxidation, and controlling high-temperature volatility.

With the addition of Exxon's proprietary additive package, SPARTAN Synthetic EP grades 150 and higher support a Timken OK load in excess of 100 lbs, compared to 60 lbs for a conventional petroleum-base EP gear oil.

Figures 7-5 through 7-8 convey the performance advantages that can be obtained from the many grades of this PAO-based synthetic EP industrial gear oil.

Oxidation of an oil—breakdown due to heat and oxygen—causes viscosity to increase, and it creates soft sludges and hard deposits that can lead to equipment failure. Among conventional petroleum-base products, a premium EP gear oil offers outstanding oxidation performance at operating conditions up to 93°C(200°F). As shown in Figure 7-5, SPARTAN Synthetic EP carries that performance to the extreme, staying clean up to 121°C(250°F).

Superior volatility control is illustrated in Figure 7-6, while pour point and viscosity characteristics can be compared in Figures 7-7 and 7-8. As can be seen, SPARTAN Synthetic EP is ideal for arctic and other cold-weather environments, because it keeps flowing even at -30°C (-22°F) and colder. Most conventional petroleum-base gear oils become too thick to pour below -10°C (14°F). Machines start easier and gear boxes run more efficiently high quality synthetic EPs.

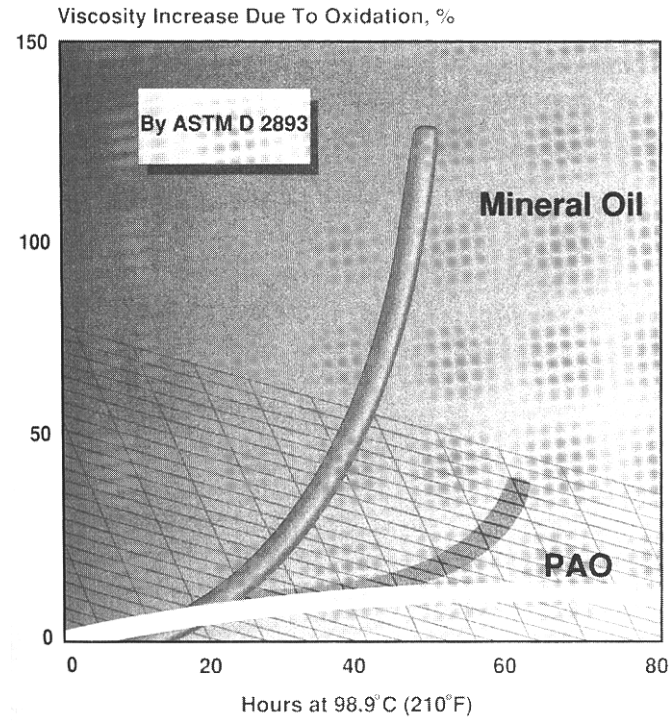

Figure 7-5. Viscosity increase due to oxidation, mineral oil vs. synthetic EP product. (Source: Exxon Company, USA, Houston, Texas.)

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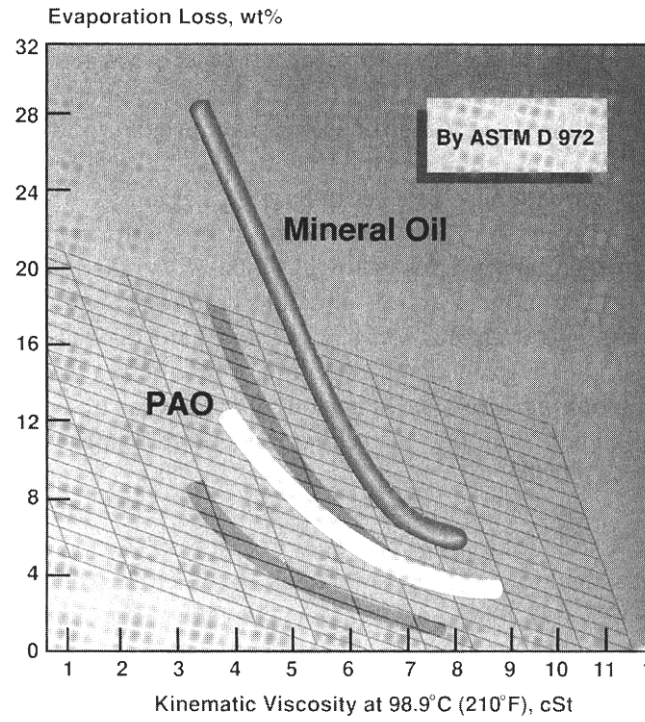

Figure 7-6. A superior synthetic EP oil will give superior volatility control to provide long-term lubrication effectiveness. Plus, the low volatility and high flash point compared to conventional gear oils give an added margin of safety at high operating temperatures. (Source: Exxon Company, USA, Houston, Texas.)

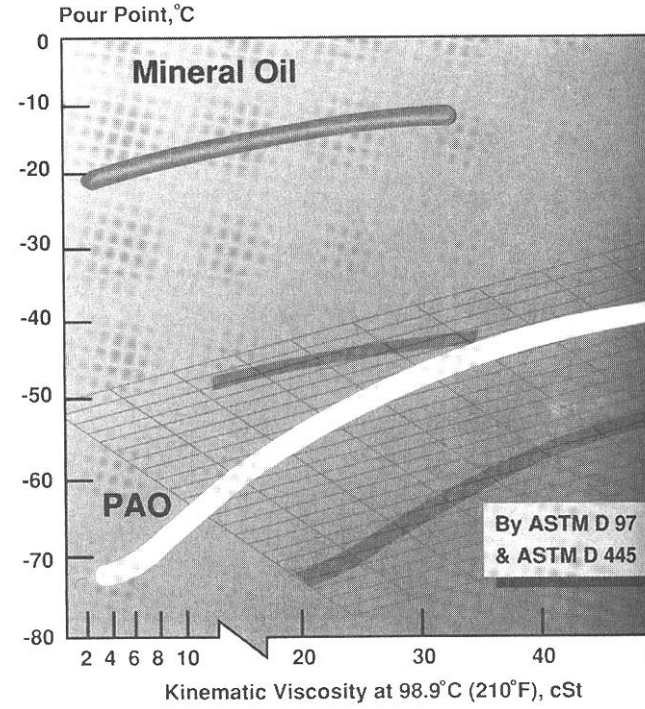

Figure 7-7. PAO-based synthetics have superior cold-weather performance. (Source: Exxon Company, USA, Houston, Texas.)

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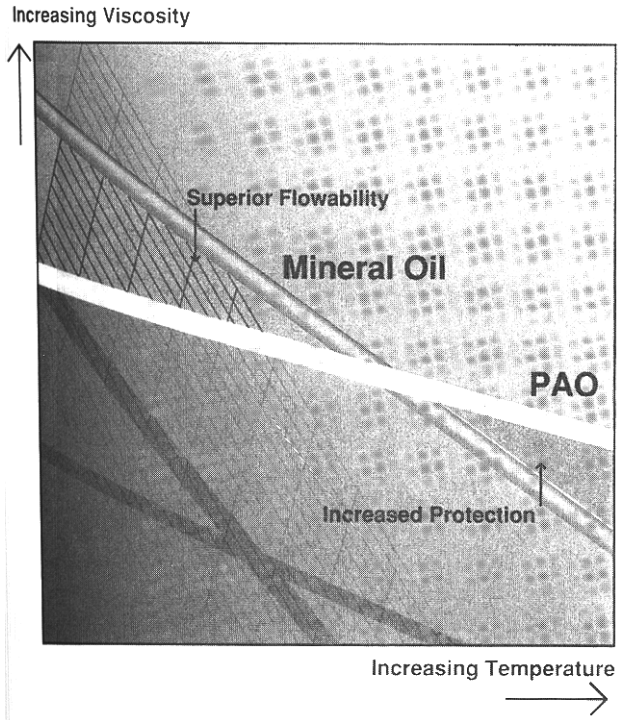

Figure 7-8. High-quality polyalphaolefin basestock helps keep viscosity stable over a wide range of temperatures. The viscosity index for SPARTAN Synthetic EP gear oils ranges from 150 to 167, compared to 90 to 100 for a conventional petroleum-based oil.

CASE HISTORIES INVOLVING PAO-BASED SYNTHETIC EP OILS

When a triple-race roller bearing on a crown roll fails, it can cost $25,000 or more to replace. One southeastern paper mill was replacing each bearing at least every two years. In one instance, a bearing lasted only nine months.

The problem arose from the crown roll's unusually low rotational speed. The machine (Figure 7-9) did not generate enough centrifugal force to keep the rollers pressed against the bearing's outer raceway, so rollers leaving the load zone stopped rotating. As each roller reentered the load zone, it skidded like an airplane tire first touching ground. Damage to the bearing raceways quickly led to bearing failure.

The competitive petroleum-base EP gear oil used by the mill couldn't stop the destruction, and use of a higher viscosity oil was not possible: the oil is shared by the hydraulic system, which would have suffered startup problems with a higher viscosity.

The switch to SPARTAN Synthetic EP brought immediate benefits: its high viscosity index meant good fluidity at cold startup conditions. Also, its outstanding lubricity protected the expensive bearings. After two full years with the Exxon synthetic product, the bearings showed no evidence of unusual wear.

The second case history involved a 20-ton overhead crane at a major Midwestern steel company which had trouble every time the weather got cold. Located above an open railcar entryway, the gear boxes of the crane (Figure 7-10) were exposed to ambient temperatures, making the crane hard to start and difficult to keep running whenever the mercury dropped. When temperatures fell to -40°C (-40°F) one winter, the crane drew so much power trying to start that it blew the system's circuit breakers.

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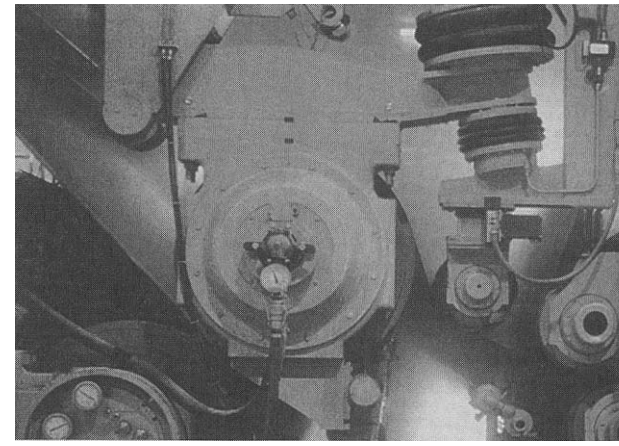

Figure 7-9. Paper machine rolls in severe duty service.

Based upon manufacturer's specifications, the crane's gear boxes were lubricated with a conventional ISO 320 EP gear oil. The pour point of this oil was -9°C (15°F), so the oil varied from stiff to solid in cold weather.

Working together, the technical services group of the oil manufacturer, steel-mill personnel, and the crane manufacturer determined that SPARTAN Synthetic EP ISO 220 would be an acceptable substitute for the petroleum-base gear oil.

SPARTAN Synthetic EP solved the problem. Its low pour point made cold-weather start-up easy, eliminating excess power drain. The high viscosity index provided good film thickness in summer temperatures, even at the lower viscosity grade. The high Timken OK Load rating ensured outstanding extreme-pressure protection. In addition, SPARTAN Synthetic EP appeared to provide energy savings, a subject touched on in the next segment of our text.

Finally, the papermaker's dilemma: To get more tonnage (Figure 7-11), run the machine faster, and turn up the heat. To get less downtime, slow the machine, and lower the heat.

SPARTAN Synthetic EP now helps a Southeastern mill run fast and hot *and* minimize downtime.

One big problem for this mill was the drive gears in the press section. Because of high ambient temperatures plus heavy loads, these gears operated continuously at 200°F. The conventional EP gear oil used by the mill oxidized to a viscous black sludgy material so fast that even oil changes every six months were not frequent enough to ensure that gears and bearings would stay adequately lubricated.

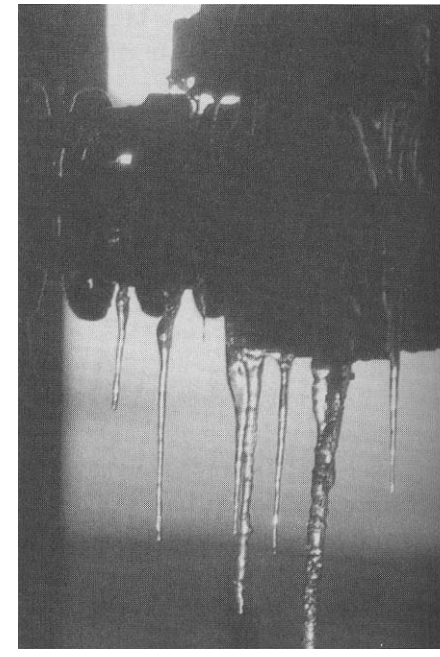

Figure 7-10. Overhead crane gear box exposed to severe ambient environment.

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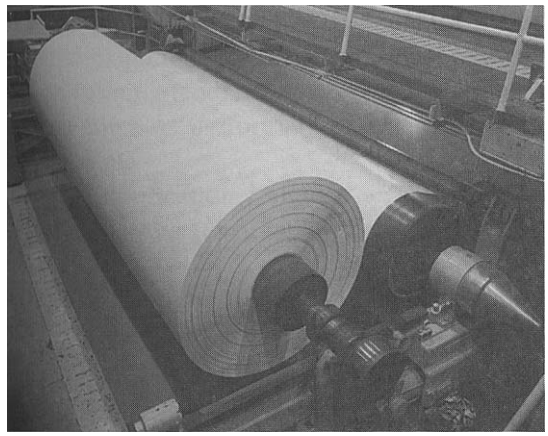

Figure 7-11. Tons of paper on a single roll.

The mill switched to SPARTAN Synthetic EP. Two years later, when the original charge of the product was routinely tested, it still met the gear manufacturer's requirements.

The long life and excellent oxidation stability of SPARTAN Synthetic EP pay dividends: fewer oil changes mean lower costs, less downtime, and less material to dispose of, and continuous on-spec performance without viscosity increase means energy-efficient operation and maximum gear service life.

DIESTERS: ANOTHER SYNTHETICS OPTION

We had earlier considered SPARTAN Synthetic EPs, a line of six long-life, extreme-pressure industrial gear and bearing lubricants manufactured from synthesized hydrocarbons, predominantly polyalphaolefins. They are designed to provide outstanding performance under severe temperatures and loads. Applications include gear boxes, industrial differentials and highly-loaded rolling contact bearings. The thermal and oxidative stability of SPARTAN Synthetic EP, superior to that of conventional gear oils, provides excellent resistance to sludging and helps ensure long lubricant life, wen under the severe conditions encountered in small, high-temperature gear boxes. Because the synthesized hydrocarbons contain no wax, these lubricants can be used in mist lubricators and in low-temperature applications.

While there is some overlapping of applications for PAOs and diesters, Exxon states that their line of diester-based SYNESSTIC (Table 7-5) is formulated to give outstanding performance in air compressors, hydraulic systems, mist lubrication systems, air-cooled heat exchanger drives, and bearings in pumps and electric motors. SYNESSTIC is particularly well-suited for outside compressors that may be subjected to a wide range of temperatures. Changing from a conventional petroleum-base lubricant to SYNESSTIC can minimize the frustrating and costly problems of hot-running equipment, premature bearing failures, damaging deposit build-up, cold-weather wax plugging and the necessity for frequent oil changes. The superior lubricity of SYNESSTIC VS. comparable petroleum oils permits bearings to run cooler, thus extending the life of the bearings and the lubricant.

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Table 7-5. SYNESSTIC typical inspections.

SYNESSTIC Typical Inspections

The values shown here are representative of current production. Some are controlled by manufacturing specifications, while others are not. All of them may vary within modest ranges.

Grade		32	68	100	150	EP 220
Viscosity						
cSt @ 40°C	ASTM D 445	30.0	65.0	96.0	143	215
cSt @ 100°C		5.5	7.5	10.1	13.6	27
SUS @ 100°F	ASTM D 2161	153	339	502	740	1108
SUS @ 210°F		44.7	51.4	60.6	73.0	132
Viscosity index	ASTM D 2270	120	77	88	89	160
Pour point, °C	ASTM D 97	-57	-37	-40	-34	-43
°F		-71	-35	-40	-30	-45
Flash Point, °C	ASTM D 93	266	271	252	249	174
°F		510	520	485	480	345
Autogenous ignition temperature, °C		385	393	413	418	393
°F		725	740	775	785	740
Specific gravity @ 15.6°C (600F)		0.926	0 957	0.963	0.959	0.884
Timken OK load, lb	ASTM D 2782	—	—	—	—	75
FZG gear test, stages		—	—	—	—	12
Demulsibility @ 54.4°C (130°F), ml oil/water/emulsion	ASTM D1401	40/40/0	40/40/0	40/40/0	40/40/0	40/40/0
Evaporative loss, 22 hr @ 98.9°C (210°F), mass %	ASTM D 972	1.7	0.20	0.30	0.30	—
Copper strip corrosion, 3 hrs @ 100°C (212°F)	ASTM D 130	1a	1a	1a	1a	1a
Rust prev., 24-hr dist. water	ASTM D 665	No rust	No rust	No rust	No rust	No rust
Panel coking, 6 hrs @ 316°C (600°F), mg deposit		9.8	9.6	6.0	9.9	—
Conradson carbon residue, mass %	ASTM D 189	0.00	0.00	0.00	0.00	—
Four-ball, 40 kg, 1800 rpm, 65.6°C (150°F), 30 min., scar diam., mm		0.30	0.40	0.40	0.40	—

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In addition, its low volatility helps reduce lubricant consumption. SYNESSTIC lubricants are rust-and-oxidation inhibited and have excellent anti-wear properties. They have very low carbon-forming tendencies due to their diester base. The SYNESSTIC EP 220 grade provides extreme-pressure performance and meets or exceeds USS 224 and AGMA 250.04 gear oil requirements.

The application range of superior diester-base synthetics is best illustrated by briefly reviewing four case histories.

- In one refinery, SYNESSTIC synthetic eliminated bearing failures in a 4,000-HP electric motor and lowered oil temperatures by more than 50%.
- In a chemical plant, SYNESSTIC 100 ended a cold-weather wax-plugging problem in an oil mist system and saved $9,375 the first year.
- In a British petrochemical operation, SYNESSTIC 32 reduced valve overhauls in a reciprocating compressor from 24 per year to one; saved $4,300 per year in energy costs; and extended drain intervals by a factor of eight.
- In a major steel plant, SYNESSTIC 100 virtually eliminated coke deposits that had caused four reciprocating compressors to be shut down every 1,500 hours for cleaning. The compressors now run 6,000 hours and longer with no problems.

Indeed, long after conventional mineral oils have blackened to coke and sludge, SYNESSTIC synthetic lubricants run clean. Their superior film strength provides better wear performance than conventional fluids, so equipment can last longer. Their low pour points and outstanding high temperature stability can eliminate seasonal oil changes and reduce volatility losses and oil carryover. SYNESSTIC fluids can even save money by saving energy.

Carbon-free Compressor Operation

A pair of 50-HP reciprocating air compressors in a chemical plant were in alternate service (one week continuously on, then off), using an ISO 150 mineral oil. Carbon deposits on discharge valves caused such operating problems that the machines required maintenance every three months.

In an operational test, one compressor was switched to SYNESSTIC 100. After more than six months, discharge valves on this compressor were substantially cleaner than they were on the unit that used mineral oil for four months.

SYNESSTIC 100 allowed compressor maintenance intervals to be doubled from three months to six, a significant saving in labor and material.

The comparison photos (Figure 7-12) tell the story.

High Film Strength for Better Wear Protection

SYNESSTIC synthetic lubricants outperform both mineral oils and competitive synthetics in film strength and lubricity. That means less wear, reduced maintenance and longer operating life for your machinery.

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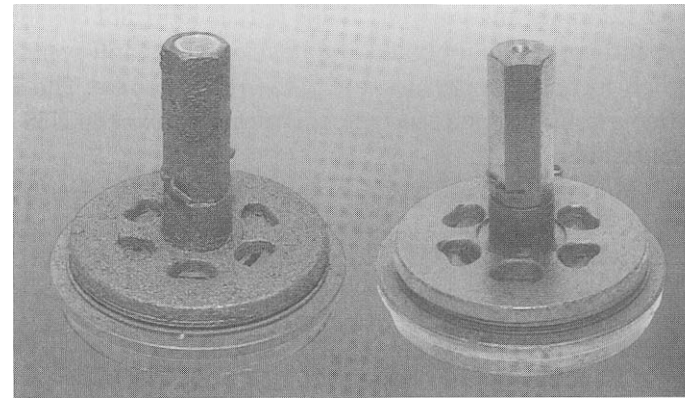

Figure 7-12. Photo on left - No. 1 discharge valve after 4 months' service with ISO 150 mineral oil. Photo on right - No. 1 discharge valve after 6 months' service with SYNESSTIC *100.*

One key to film strength is the polar molecules of the SYNESSTIC diester base stock. These molecules line up on metallic surfaces like the nap of a carpet, creating a strong lubricant film that helps prevent metal-to-metal contact.

A proprietary additive package enhances these natural anti-wear properties, as can be shown in the four-ball wear test. Here, a steel test ball rotates on top of three other stationary steel test balls. At the end of the test, the average diameter of the wear scar on the three lower balls shows how much wear has occurred. The graph, Figure 7-13, shows that SYNESSTIC surpasses competitive synthetic products in preventing wear.

As illustrated in Figure 7-14, many synthetic lubricants excel in wear protection tests over equivalent viscosity mineral oils. The bearing wear experience with an ISO grade 32 synthetic is typically similar to that of an ISO grade 68 mineral oil.

These facts helped a large Northeastern refinery. Here, the mineral oils traditionally used to lubricate the hot liquid pumps for the pipe stills could not prevent excess bearing wear. In fact, bearing failures caused more than 40% of total pump failures.

Introduction of SYNESSTIC 100 essentially eliminated bear-bearing failures, reducing the occurrence to only 3% of all pump outages. The increase in the on-stream reliability of the

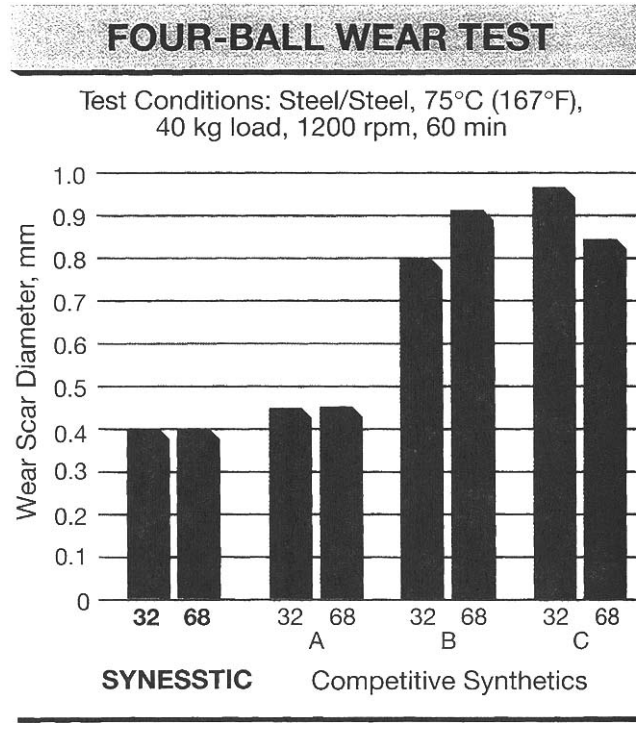

Figure 7-13. Wear test results, SYNESSTIC *vs. competitive synthetics.*

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distillation unit not only saved capital and labor costs to repair damaged equipment, it also improved the economic efficiency of the entire process.

Long-term Oxidation Resistance

Lubricants must be able to resist degradation when exposed to oxidizing conditions for long periods. The test results below show the long-term stability of SYNESSTIC fluids. In this severe laboratory (110°C copper catalyst, warm air current, as illustrated in Figure 7-15), all of the oils showed initial control of oxidation. But once the oxidation inhibitor in the conventional mineral oil was consumed, that oil oxidized rapidly. Its degradation produced acidic by-products.

Unlike the mineral oil, all three SYNESSTIC grades resisted oxidation for 3,000 hours and more, evidence of the inherent chemical stability of this lubricant.

Negligible Carbon Deposits

When mineral oils are heated enough, they break down, leaving varnish, carbon and coke deposits that can be extremely damaging. SYNESSTIC synthetics offer dramatic improvements in thermal stability.

Results in the Panel Coker Test, Figure 7-16, illustrate the advantage. Hot oil was splashed onto these metal test panels at 260°C (500°F) and 274°C (525°F) in the presence of air for 6 hours, simulating a stressful application. The obvious carbon deposits on the test panels show the dramatic difference between SYNESSTIC and conventional mineral oils.

Low Pour Point Advantage

SYNESSTIC fluids flow easily at temperatures where conventional lubricants almost refuse to budge. This means easy startup for intermittent and cold-weather operations. And it means you can eliminate wasteful and time-consuming seasonal oil changes.

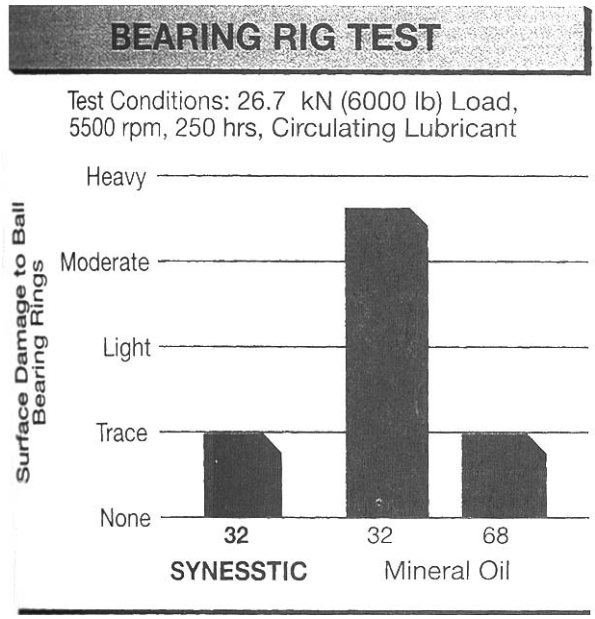

Figure 7-14. Laboratory studies with an instrumented bearing test rig demonstrate that a low viscosity SYNESSTIC can provide the same protection as a higher viscosity mineral oil. In the test illustrated in this graph, the additive packages of all three lubricants were identical—only the base changed. Because a lower viscosity grade can achieve the same degree of protection, you may be able to save energy and reduce costs.

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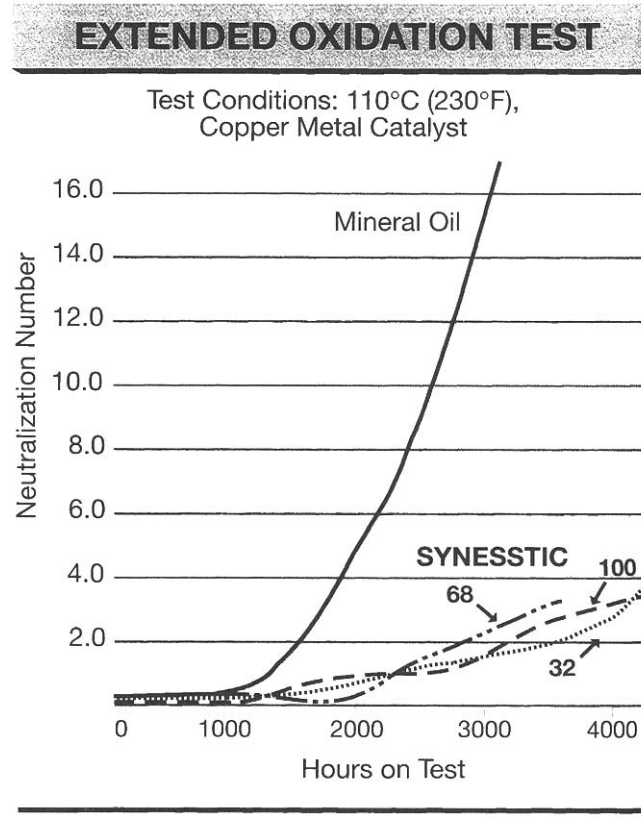

Figure 7-15. Oxidation tests show diester-base synthetics excel over mineral oils.

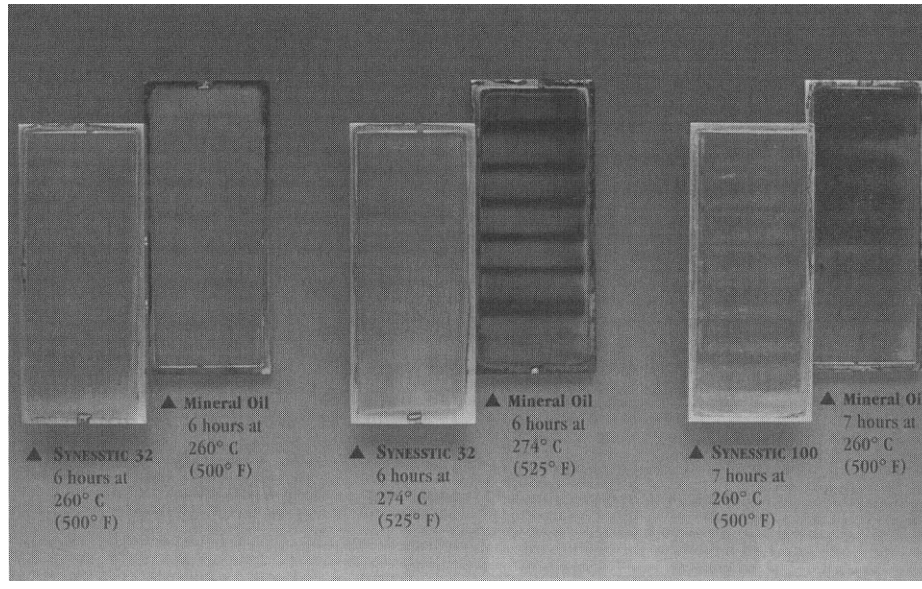

Figure 7-16. Negligible carbon deposits on the SYNESSTIC test panels show how SYNESSTIC lubricants help keep machine elements clean.

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Unlike petroleum oils, which typically contain some wax, SYNESSTIC synthetics have no wax to hinder their flow.

SYNESSTIC lubricants invariably show lower pour points than mineral oils of comparable grade, as shown in Figure 7-17 and 7-18. Although mineral oils generally undergo cold solvent treatment and filtration to remove most of the waxy hydrocarbon fractions, traces of wax that remain can freeze out at low temperatures. That translates to less-than-optimum lubrication for cold-weather and intermittent operations.

At low temperatures, wax crystals in conventional lubricants can clog mist reclassifier fittings. That means that expensive bearings and other machine elements may fail from lack of proper lubrication. Because SYNESSTIC fluids contain no wax, low temperatures are no problem, and mist systems can operate dependably year-round.

Easy Cold Startup, Low Friction and Energy Savings

The microscope shows why SYNESSTIC lubricants help machinery start so easily in the cold. Magnified 360 times (Figure 7-19), SYNESSTIC 32 is free of wax at -18°C (0°F), while a

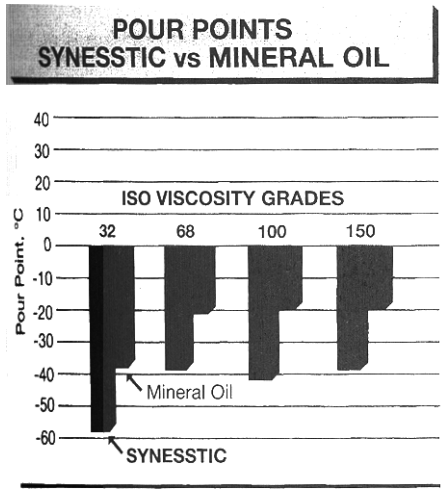

Figure 7-17. Pour point advantage of SYNESSTIC diester lubricant over mineral oils.

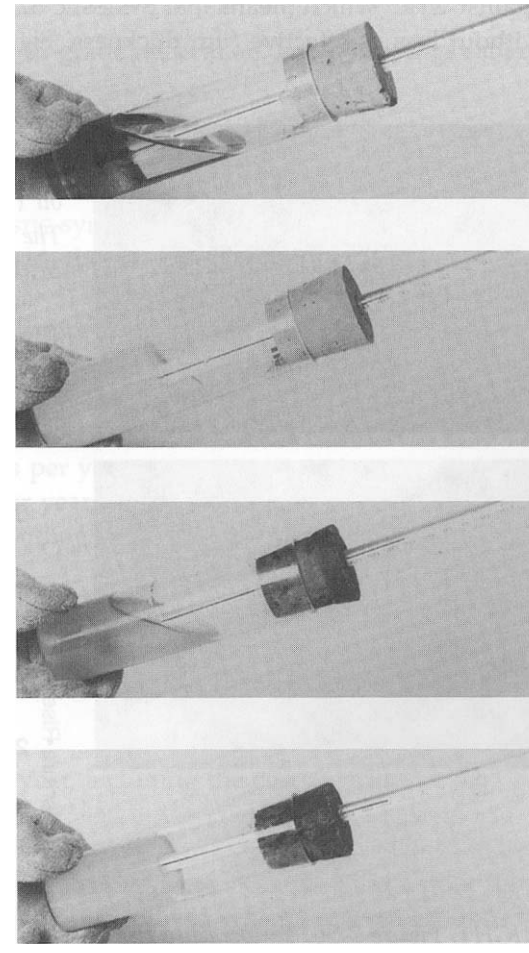

Figure 7-18. At comparative test temperatures, the mineral oils solidify while the SYNESSTIC 32 and 100 grades remain free flowing.

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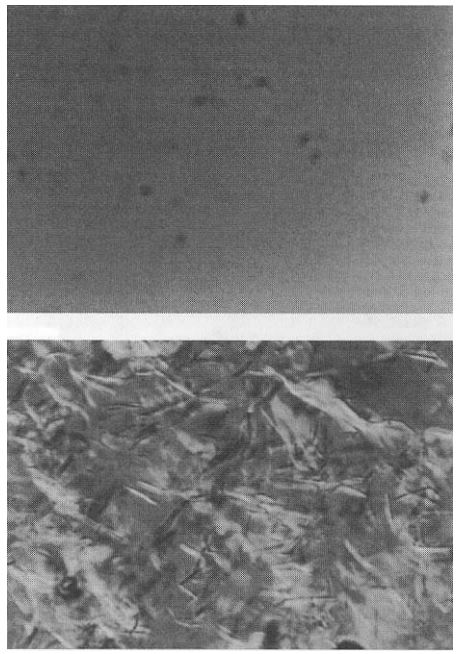
typical mineral oil shows significant crystallization. Moreover, the diester-base lubricant reduces friction so effectively that the temperature of lubricated bearings remains much lower than it does in bearings lubricated with mineral oil. Lower temperature helps the lubricant last longer. And it means that bearings last longer too, because a cooler lubricant has a relatively higher effective viscosity and maintains a more reliable film thickness. Lower bearing temperatures also provide a better margin of safety against thermal fatigue effects.

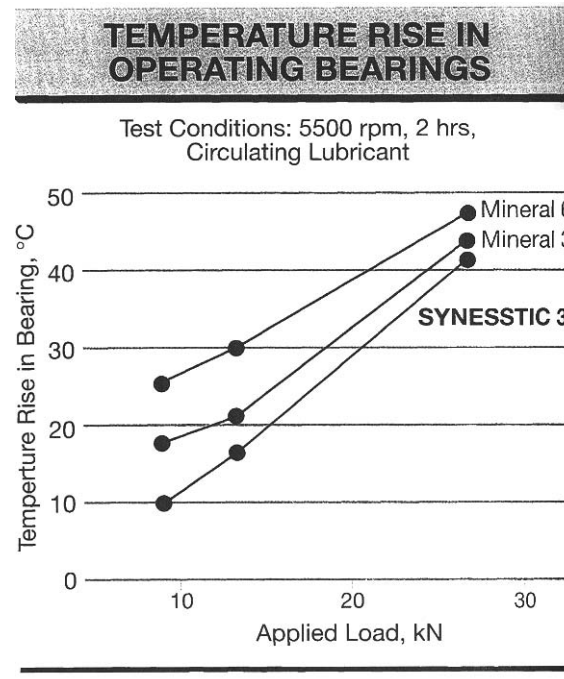
Figure 7-20 compares the temperature rise in test bearings with three lubricants that differ only in base stock (all have the same additive package). As expected, the lower the viscosity, the less the temperature increases as the load goes up. But a comparison of identical viscosity grades shows that the SYNESSTIC synthetic base stock stays significantly cooler than the petroleum-base lubricant.

Less friction and lower temperatures indicate that less energy is being wasted. As a result, energy bills for equipment switched to SYNESSTIC lubricants may go down as much as 7% or more, even if there is no switch to a lower viscosity grade.

A controlled test series showed that SYNESSTIC lubricants stay cooler and protect against wear, which means that SYNESSTIC 32 can be substituted for an ISO 68 mineral oil without loss of effective film thickness. Figure 7-21 shows the energy reduction in test



LEFT: Figure 7-19. At −18°C, SYNESSTIC 32 (top photo) has no wax crystals, while a typical mineral oil (bottom photo) shows significant crystallization. The dark spots in the SYNESSTIC photo are air bubbles in the sample.



RIGHT: Figure 7-20. Temperature rise in bearings lubricant with different oils.

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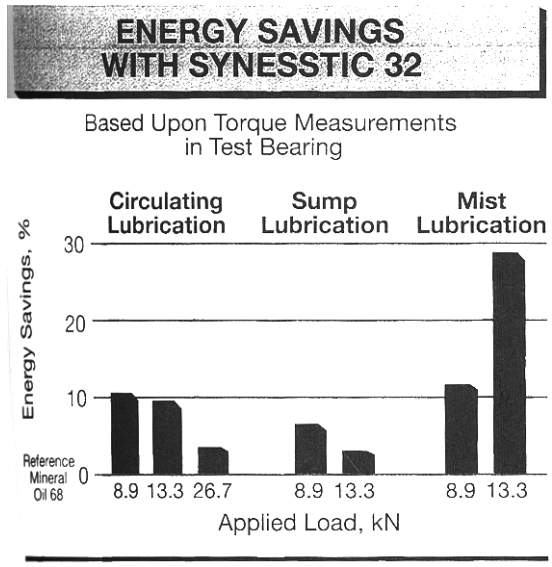

Figure 7-21. Frictional energy reduction achievable with SYNESSTIC 32 vs. mineral oil 68. Note that these two lubricants have the same wear protection quality.

applications using SYNESSTIC 32 instead of the 68-grade mineral oil. Energy savings ranged from 3% to 29% in these laboratory bearing tests.

Reduced Maintenance, Fuel Savings

At a Gulf Coast plant location, engineers ran a series of tests to measure the energy savings that could be achieved using SYNESSTIC synthetic lubricants. The tests were conducted in two different compressor types, with the following results:

- Ingersoll-Rand TVR-21 Reciprocating Compressor, a 1,200-HP compressor with six double-acting compressor cylinders. In tests comparing SYNESSTIC 32 with a premium ISO 100 mineral oil, SYNESSTIC 32 achieved:
  - — 2.9% less power consumption
  - — $5,340 in natural gas fuel savings per year
  - — $6,160 in maintenance savings per year
  - — $6,596 net operating savings, including the higher cost of SYNESSTIC 32.

- Ingersoll-Rand Centac 4-stage Centrifugal Compressor, a 900-HP (670 kW) electric motor drive operating between 22,400 and 47,900 rpm. In this compressor, SYNESSTIC 32 was substituted for a premium ISO 32 mineral oil. SYNESSTIC achieved:
  - — 1.0% less power consumption
  - — $3,624 savings in electricity
  - — $1,936 net operating savings per year, including the cost of SYNESSTIC 32.

Anti-Foaming Properties Prevent Wear, Oil Carryover

Air entrainment and foaming can cause excessive wear, because air is a poor lubricant! In compressors, foaming can also lead to oil carryover, which removes oil from the system and causes lubricant starvation.

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Tests show that SYNESSTIC fluids release air rapidly, whether it be entrained air (bubble size of 1 mm or less) or foam (bubble size larger than 1 mm). In the test shown in Figure 7-22, lubricants were heated to 75°C (165°F), stirred in a Waring Blender at high speed for one minute and placed in a glass cylinder, where the time to clear was measured. Regardless of viscosity, SYNESSTIC released entrained air within two minutes; mineral-oil equivalents took nine to 18 times longer.

Composition Control Means Volatility Control, Safety and Long Life

Each viscosity grade of SYNESSTIC contains a selected molecular composition with well-defined volatility characteristics and no undesirable "light ends." The purity of this lubricant shows clearly in the narrow-cut distillation band of Figure 7-23, taken from a Gas Chromatograph Distillation (ASTM D 2887) evaluation.

Typical industrial-grade mineral oils show a much broader distillation band due to their natural origin. Mineral oils include significantly more light ends, which makes these lubricants more volatile at lower temperatures.

The relative absence of light-end volatility in SYNESSTIC translates to longer product life and improved safety: The flash point of Synesstic 32, for example, runs about 30°C (55°F) higher than a comparable mineral oil, and auto-ignition temperatures are 80°C (140°F) higher.

Field Experience with Diester Lubricants

After the initial laboratory work in the development of SYNESSTIC products, Exxon research personnel scaled up the testing with the aid of Exxon refinery and plant engineers. The project team evaluated SYNESSTIC formulations in a myriad of equipment

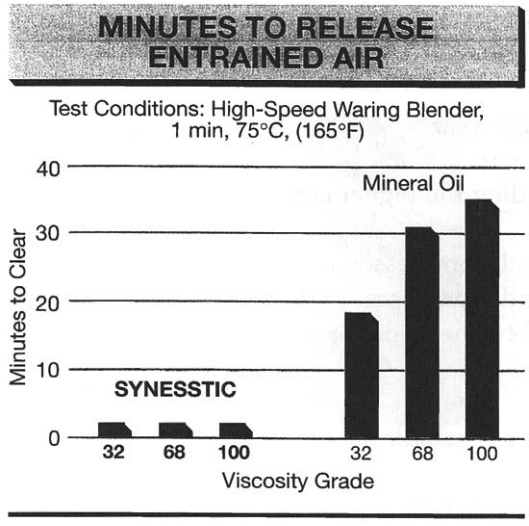

Figure 7-22. Diester-base lubricants will release entrained air much more rapidly than mineral oils.

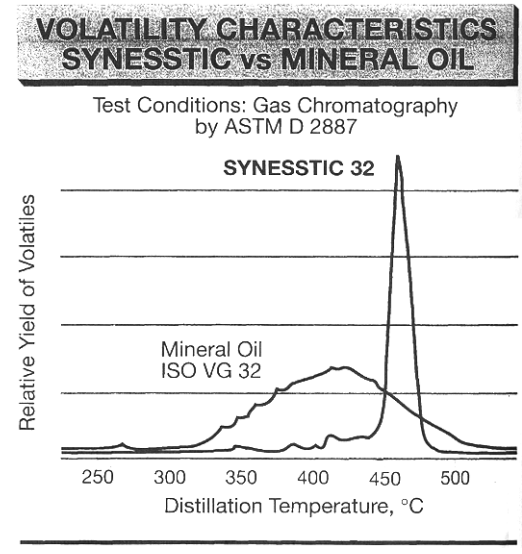

Figure 7-23. There is very little light-end volatility in this diester-base synthetic hydrocarbon lubricant.

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types, paying special attention to applications with a history of lubrication problems.

This diester lubricant solved one problem after another, and today these synthetics find wide use at Exxon:

At one refinery complex, SYNESSTIC products are used in several hundred pieces of equipment, ranging from 1 to 800 HP, from 5 to 15,000 rpm, and from old reciprocating compressors to new high-speed pumps.

This company also uses these diester lubricants in mist systems in the refinery and tank field. Some of the recorded maintenance savings at one location include:

- $46,000 per year by stopping failures of furnace air preheaters.
- $16,000 per year by eliminating valve repair on a gas engine reciprocating compressor.
- 350 work-hours per year by eliminating seasonal lube changes on fin-fan gear boxes.

It has been estimated that the change to SYNESSTIC synthetic lubricants at this one refinery translates to net savings between $100,000 and $200,000 each year.

APPLICATION SUMMARY FOR DIESTER-BASE SYNTHETIC LUBRICANTS

Diester-base synthetics are cost justified whenever a plant requires a combination of exceptional oxidation resistance, outstanding high-temperature stability, low-temperature fluidity, deposit prevention and long-term cleanliness.

SYNESSTICS can extend drain intervals, as illustrated in Table 7-6. Moreover, these diester-base lubricants inevitably help prevent the high cost of machine servicing and replacement. They help avoid lubricant losses attributable to foaming and high-temperature evaporation; they can reduce energy costs and exhibit favorable viscosity-temperature relationships, Figure 7-24.

Table 7-6. Diester-base synthetic lubricants extend oil drain intervals.

EQUIPMENT	METHOD	PREVIOUS	CURRENT
Rotary Screw Compressor	Circulation	2000 hours	8000 hours
Centrifuge Gear Case	Splash	3 months	24 months
Fin Fan Gear Unit	Splash	6 months	2 year plus
Parallel Shaft Gear Reducer	Splash	3 months	1 year plus
Sundyne® Gear Unit	Circulation	6 months	2 year plus
Reciprocating Pump	Splash	3 months	8 months plus

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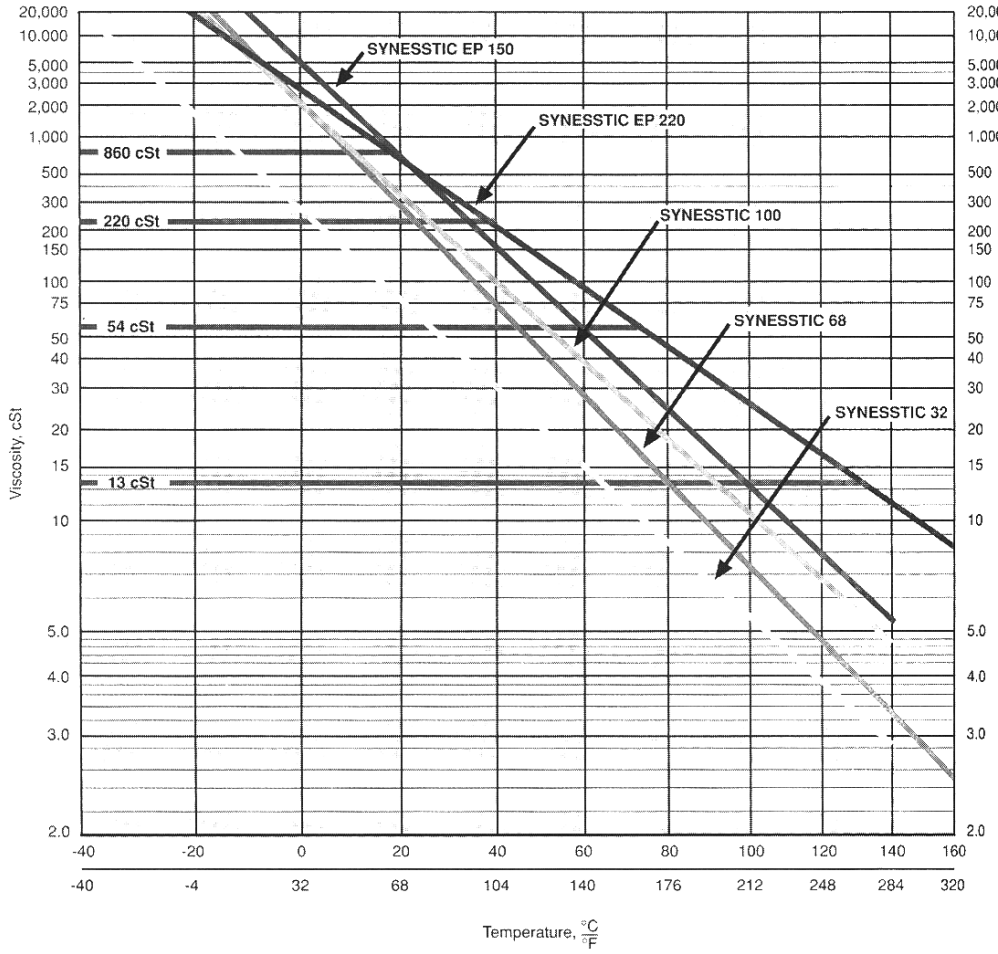

Figure 7-24. Viscosity-temperature curves for different SYNESSTIC grades.

- SYNESSTIC lubricants perform exceptionally well in a wide variety of compressors. In reciprocating compressors, these products resist high temperatures, avoid fouling of discharge valves, extend drain intervals, reduce friction and wear, and offer potential energy savings. In tests of more than 50 makes and models of reciprocating compressors from all major vendors, SYNESSTIC synthetics invariably gave great improvement over petroleum-base lubricants (Figure 7-25).

  In rotary compressors, where there is continuous intermingling of lubricant and gas, the excellent oxidation performance of SYNESSTIC synthetics helps prevent deposits and reduces downstream oil carryover. Compressed gas is cleaner, and the compressor consumes less lubricant.

- Oil mist lubrication is gaining popularity. Modern mist systems deliver uncontaminated lubricant, extending bearing life and reducing failures. At the same time, mist

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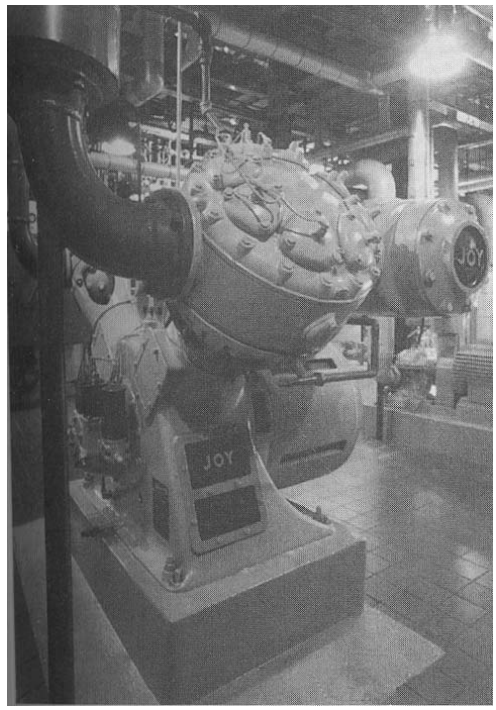

Figure 7-25. SYNESSTIC film strength offers improved bearing for all types of compressors.

systems generally consume less total lubricant than traditional lubrication systems do. Machinery running with mist lubrication produces higher work output and saves energy. And finally, mist systems have no moving parts to cause problems.

One problem that can arise with mist systems is cold-weather plugging in the reclassifier fittings, where wax present in the lubricant can precipitate out and obstruct the narrow passages. SYNESSTIC products prevent this because they contain no wax. Today the SYNESSTIC solution is being used in a variety of mist applications, including:

- — Positive displacement pumps
- — Centrifugal pumps
- — Steam turbines
- — Furnace air preheaters
- — Fans and blowers
- — Electric motors

- The good film strength and anti-wear protection of SYNESSTIC synthetic lubricants deliver excellent field performance in high-speed integrally geared pumps and other equipment under moderate loads. Field experience shows that SYNESSTIC 32 can be an effective and truly superior replacement for the automatic transmission fluids commonly found in high-speed gear boxes.

- While many hydraulic systems do not present extreme performance challenges in terms of oxidation, thermal stability, or wear resistance, SYNESSTIC synthetics often solve operating problems that do exist. In particular, the cleanliness-promoting solvency of SYNESSTIC can help overcome sluggish or erratic valve actuation and lead to faster, smoother system operation.

Oil change procedures and materials compatibilities are summarized in Tables 7-7 and 7-8, respectively.

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Table 7-7. Oil changes procedures for SYNESSTIC diester lubricants.

Oil Change Procedures

SYNESSTIC synthetic lubricants have very good solvency characteristics, which helps keep machine components clean. However, this also means that you should observe certain precautions when changing from a mineral oil to SYNESSTIC. The following procedures are guidelines only; for help, contact your local supplier.

Once-through: Oil mist systems, reciprocating compressor cylinder lubrication, oil-injected screw compressors.

1. Drain mineral oil from reservoir and fill with the proper grade of SYNESSTIC.
2. If possible, flush SYNESSTIC through lube lines for five to ten minutes to remove old deposits.
3. If step 2 is not possible, operate lubrication system normally and observe lubrication points closely for any signs of plugging from displaced mineral-oil deposits.
4. When all deposits have been removed, return the machine to normal service.

Small Sumps: Pumps, steam turbines, small gear sets, other units with reservoirs of 10 gallons or less.

1. Drain mineral oil, inspect internal condition of the machine, and hand clean as much as practical.
2. Fill with proper grade of SYNESSTIC and run machine for one to two hours.
3. Drain SYNESSTIC synthetic into suitable container, refill and start up machine.
4. Take sample for oil analysis after two days.

Large Sumps: Gear units, reciprocating compressors, units with reservoirs of 10 gallons or more.

1. If possible, switch to SYNESSTIC after a machine overhaul. Ensure that most residual mineral oil has been removed, fill with proper grade of SYNESSTIC; and start up using normal procedures.
2. If step 1 is not possible, drain mineral oil; inspect internal condition; hand clean as much as practical.
3. Fill with proper grade of SYNESSTIC and start up the machine using normal procedures.
4. Take a sample for oil analysis after one and seven days.
5. If condition of lubricant deteriorates significantly between the one-day and seven-day sample, drain and refill with SYNESSTIC. Repeat step 4.

Circulating Oil: Centrifugal compressors, flooded rotary compressors, gear units, large pumps, etc.

1. Drain mineral oil from the system as completely as possible.
2. Clean the suction strainers of lube oil pumps and install new filter elements, if applicable.
3. Fill with the proper grade of SYNESSTIC and start up the system using normal procedures.
4. Monitor the filter condition carefully for any sign of plugging during the first week of operation.

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Table 7-8. Compatibility with other lubricants, seals, paints, plastic and gases.

Other Lubricants

SYNESSTIC synthetic lubricants are completely compatible with all other mineral oil and synthetic-base industrial lubricants. From a performance standpoint, the oxidative stability of the resultant SYNESSTIC and mineral oil blend deteriorates as the mineral oil content increases.

Note that silicone-base oils are incompatible with both SYNESSTIC synthetics and mineral oils.

Seal Material	Paints and Coatings	Gases
Acceptable	*Acceptable*	*Recommended*
Fluorocarbon (Viton, PTFE)	Epoxy	*Inert*
Fluorosilicone rubber	Baked phenolic	Argon
Epichlorohydrin	Two-component urethane	Blast furnace gas
Polyacrylate rubber	Moisture-cured urethane	Carbon dioxide
Polyurethane		Helium
Medium- and high-nitrile rubber	*Marginally Acceptable*	Hydrogen
(Buna N, NBR) with more	Phenolic	Neon
than 30% acrylonitrile	Industrial latex	Nitrogen
	One-component urethane	Syngas
Unacceptable	Alkyls (baked finish preferred)	
Polysulfide		*Hydrocarbon*
Chloroprene rubber	*Not Recommended*	Acetylene
Butyl rubber	Acrylic	Butadiene
Natural rubber	Household latex	Butane
Ethylene/acrylic (polyacrylate)	Vinyl (PVC)	Butylene
Ethylene-propylene copolymer (EPM)	Varnish/lacquer	Coke oven gas
Ethylene-propylene terpolymer (EPDM)		Isobutane
Low nitrile rubber		Isobutylene
(Buna N, NBR) with less		Methane
than 30% acrylonitrile		Propane
Styrene-butadiene rubber		
(Buna S, SBR)		*Not Recommended*
Chlorosulfonated polyethylene		Ammonia
(Hypalon)		Chlorine
Isoprene synthetic		Freon
Silicone rubber		Hydrogen chloride
Butadiene rubber		Hydrogen sulfide
Urethane		Nitrous oxide
		Oxygen
		Sulfur dioxide

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HIGH FILM STRENGTH SYNTHETIC LUBRICANTS

The author has reviewed in excess of 100 user feedback documents relating to high film strength synthetic lubricants. The products of one such company, Royal Purple (Humble, Texas) have replaced competitive lubricants of the same viscosity with the following results:

1) reduced temperatures (10-60°F)
2) reduced vibrations (even critical bearings have had vibration reduced and stabilized to normal)
3) reduced consumption of frictional energy (10-30%)
4) reduced equipment noise

None of these significant performance improvements is viscosity-related, yet in new equipment design, engineers use a formula that depends only on oil viscosity to determine bearing load carrying capacity and bearing life. Using only oil viscosity in these calculations is inaccurate. To be accurate, design engineers should consider the performance contributions of other factors in preventing bearing failure. For example, design engineers do not take into consideration the different performance properties of base oils, such as paraffin oil, naphthenic oil, aromatic oil, synthetic oil, etc. More importantly, engineers do not recognize contributions from additive technology. These are more significant, and more important, than either viscosity or base oil in determining load-carrying capacity and bearing life. Royal Purple synthetic lubricants are modern formulations containing superior, unique additive technology making them super bearing lubricants, protecting bearings, and extending bearing life far beyond design engineers' calculations using viscosity only. These unique, proprietary bearing performance properties are important.

Oil Film "Toughness" Increased

Although Royal Purple uses a combination of PAO and diester base stocks, it may differ from the formulations of other suppliers. This company blends their products with Synerlec™, a proprietary, high load carrying, tough, tenacious, slippery synthetic film which is more important than oil viscosity/thickness in protecting bearings. Synerlec's™ tough film adheres "ionically" to bearings, giving superior protection, even under shock load conditions. Synerlec™ is so tough that a light ISO 32 grade oil with Synerlec™ protects bearings better than a heavy ISO 680 oil which depends only on viscosity for protection. Synerlec's™ tenacious adhesion to bearings prevents bearing wear during operation, and remains on bearing surfaces to prevent wear during start-up.

The most common explanations for premature bearing failures are misalignment, imbalance, extreme service duty, etc.—conditions that occur frequently in a world where more equipment is repaired with hammers than with lasers. Consequently, bearings frequently operate under stresses that exceed design standards, and frequently fail. These explanations are so easy to accept. They explain away the problems, especially if one accepts the premise that one bearing lubricant is pretty much like another.

But bearings don't fail suddenly, they fail gradually. Predictive maintenance vibration technology can identify the first signs of bearing distress and accurately document the path to destruction. First, the bearing surfaces begin to smear or gall, creating rough

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surfaces that cause vibrations. Once bearing surfaces begin to deteriorate, a destructive pattern of wear, galling and vibration begins which feeds on itself until the bearings ultimately develop stress fractures and disintegrate.

Rolling element bearings will smear, gall or begin to fail, whenever the load-dependent stress exceeds the ability of the lubricant to protect the bearing surfaces. Where bearings have already begun to fail, Royal Purple's tough Synerlec™ film immediately arrests the galling process and allows damaged bearing surfaces to polish and heal over allowing bearings to remain in service. Synerlec™ greatly increases equipment reliability because bearings are protected from the kinds of stresses that regularly occur in the real world where operating conditions are less than ideal.

For example, Figure 7-26 shows the vibration trend data observed after converting an external washer filter in a pulp mill bleach plant from a mineral oil to a high film strength synthetic lubricant. Synthetic oils with greater film strength allow rolling element bearings to cross spall marks and other surface irregularities with reduced impact severity. As a result, some deteriorating bearings have been "nursed along" by a switch to high film strength synthetics.

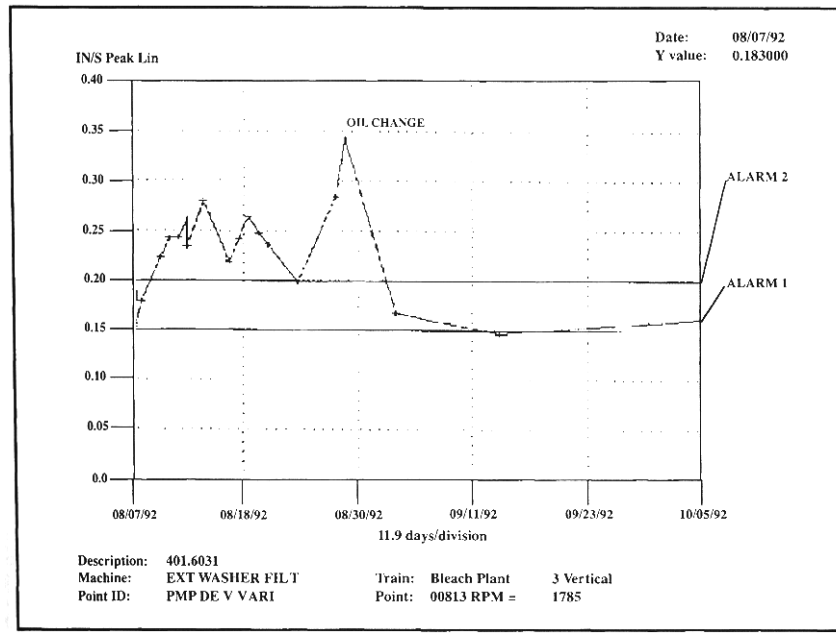

Figure 7-26. The vibration trend data observed after converting an external washer filter in a pulp mill bleach plant from a mineral oil to a high film strength synthetic lubrication.

Figure 7-27 shows vibration data from a multistage air blower at a fiber spinning plant. Conversion to a high film strength synthetic lubricant reduced vibration severity from 0.155 ips to 0.083 ips and reduced the bearing housing temperature by 20°C.

Another fiber spinning plant application was a 10 hp centrifugal pump. The overall vibration level was acceptable at 0.068 ips; however, bearing housing temperatures of

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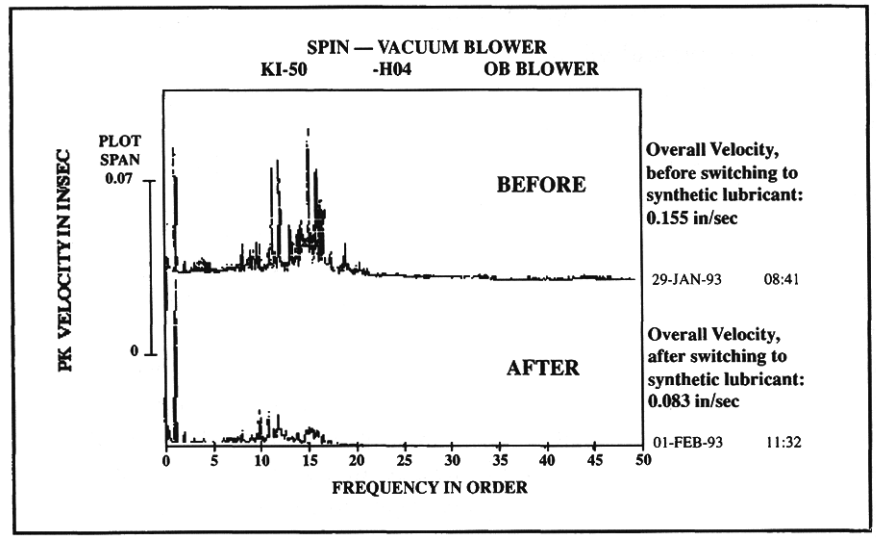
SPIN — VACUUM BLOWER
KI-50 -H04 OB BLOWER
PLOT SPAN 0.07
0
PK VELOCITY IN IN/SEC
BEFORE
AFTER
Overall Velocity, before switching to synthetic lubricant: 0.155 in/sec
29-JAN-93 08:41
Overall Velocity, after switching to synthetic lubricant: 0.083 in/sec
01-FEB-93 11:32
0 5 10 15 20 25 30 35 40 45 50
FREQUENCY IN ORDER

Figure 7-27. Vibration data from a multistage air blower at a fiber spinning plant. Conversion to a synthetic lubricant reduced vibration severity from 0.155 ips to 0.083 ips and reduced the bearing housing temperature by 20°C.

175°F were considered borderline when operating on a premium grade mineral oil (Figure 7-28a). After conversion to a high film strength synthetic lubricant, the overall vibration was reduced to 0.053 ips and the bearing housing temperature was reduced to 155°F (Figure 7-28b. In addition to the vibration and temperature reductions, motor amperage was reduced from 5.7 amps/phase on the premium mineral oil to 4.4 amps/phase with the synthetic lubricant.

Testing Corroborates Field Experience

In August 1992, Kingsbury, Inc., completed the testing of a high film strength ISO Grade 32 synthetic lubricant in their thrust bearing test machine. At low speeds and loads, there appeared to be little difference between this lubricant and identical premium grade mineral oils of the same viscosity. However, above 550 psi and 10,000 rpm, Kingsbury found the synthetic to be responsible for a 15°F reduction in bearing temperature and as much as a 10 percent decrease in frictional losses. As a result, Kingsbury approved this formulation for use with their bearings and recommended it for extreme service conditions.

In a parallel effort, a comparison was made of the lubricating properties of a specially formulated diester-base lubricant to those of a premium-grade mineral oil currently in service in petrochemical plant equipment. Two synthetic lubricants and two mineral oils of different viscosities were compared. The test results indicated that the synthetic lubricant, having a viscosity of 32 cSt at 100°F, offered long-term contact surface protection equivalent to that of the base line mineral oil which had a viscosity of 68 cSt... without reducing bearing surface life below the theoretically predicted levels. The same wear protection was not achieved with a reduced viscosity mineral oil, prompting a major

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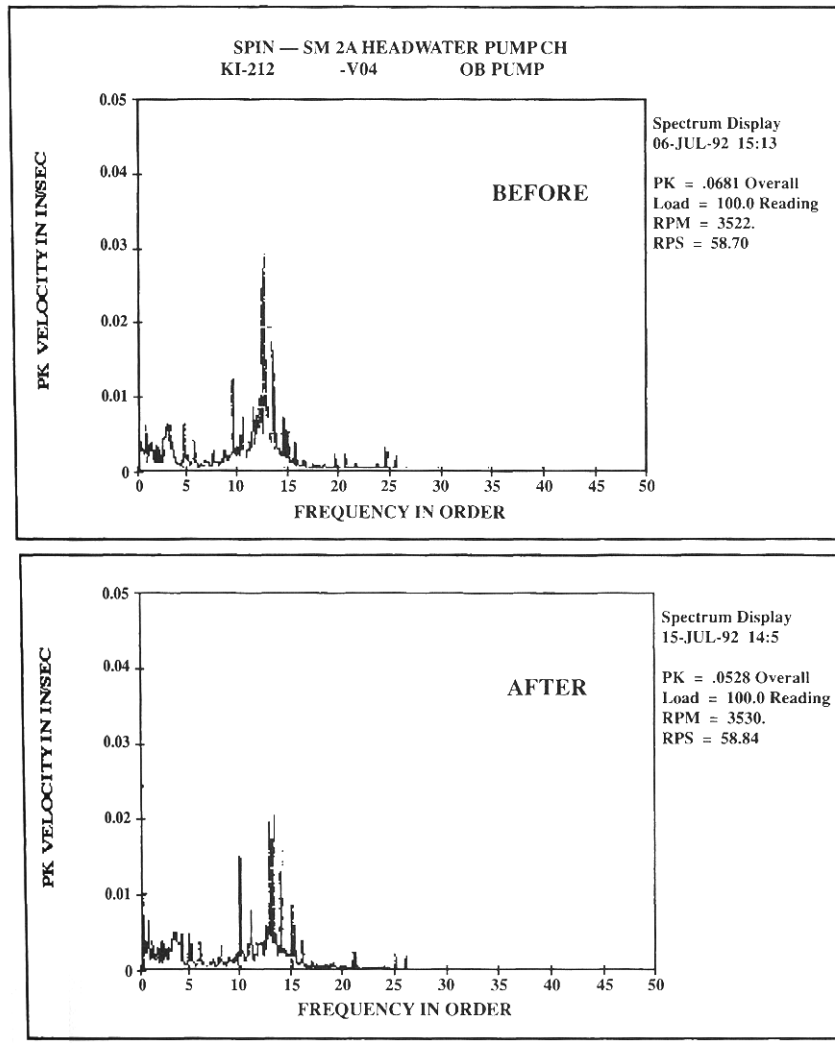

Figure 7-28(a) (top). The overall vibration level of a 10 hp centrifugal pump was 0.068 ips; however bearing housing temperatures of 175°F were borderline when operaing on a premium grade mineral oil.
Figure 7-28(b) (bottom). After conversion to a high film strength synthetic lubricant, the overall vibration was reduced to 0.053 ips and the bearing housing temperature was reduced to 155°F. In addition to the vibration and temperature reductions, motor amperage was reduced from 5.7 amps/phase on the premium mineral oil to 4.4 amps/phase with the high film strength synthetic lubricant.

major manufacturer of rolling element bearings to discontinue recommending the lower viscosity mineral oil for ball and roller bearings.

The lower viscosity synthetic lubricant provided projected energy savings of $75,000 per year when all petrochemical plant applications were considered.

Reduced vibration intensity will usually translate into an extension of equipment life. This is graphically illustrated in Figures 7-29 and 7-30.

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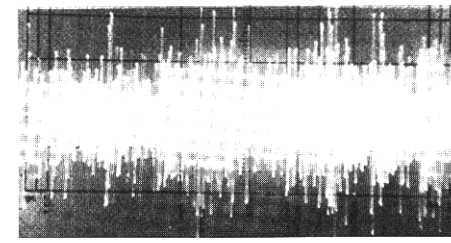
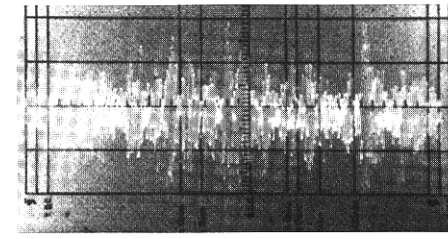
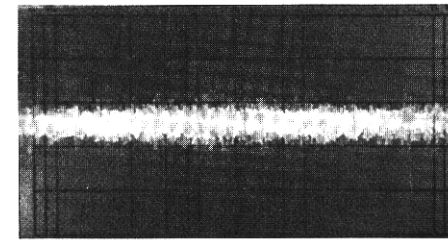
(Pictures taken with Tektronik 5113 Engine Analyzer)



Gas engine turbocharger on premium grade oil.



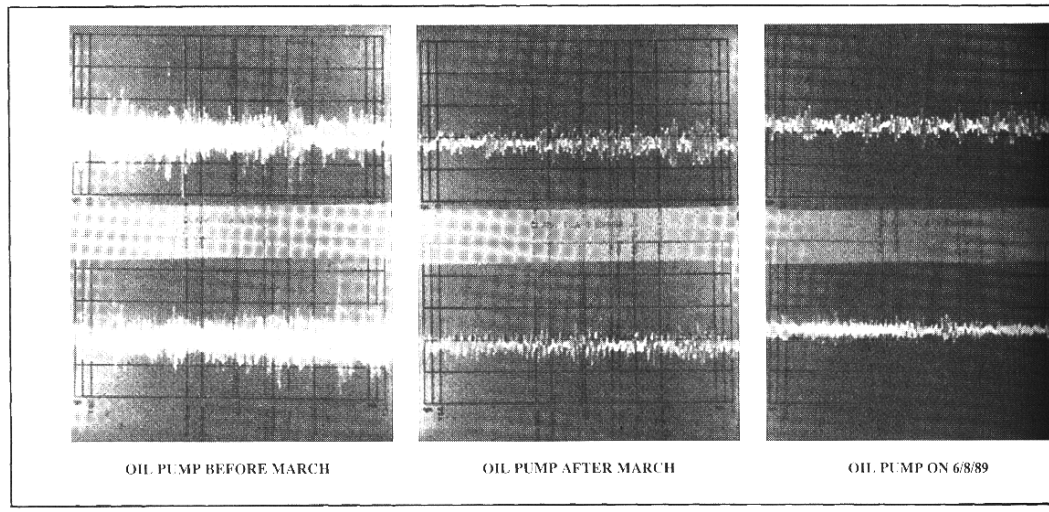
Same turbocharger after 2 days on Royal Purple.



Turbocharger after 3 months on Royal Purple.

RIGHT: Figure 7-29. The vibration shock pulse activity of a compressor turbocharger before and after conversion to a high film strength synthetic lubricant. The turbocharger experienced a 3:1 reduction in vibration severity in the high-frequency spectrum.

BELOW: Figure 7-30. The vibration shock pulse activity of a compressor oil pump before and after conversion to a high film strength synthetic lubricant. The oil pump experienced a 5:1 reduction in both the outboard and inboard ends (top and bottom respectively). In this application a tenacious, yet slippery oil film has reduced vibration severity by "peening over" the asperities on the metal surfaces.



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Parts Look Better

The same properties in Synerlec™ that allow galled bearing surfaces to heal-over also allow new bearings to properly mate with the race by "micro-polishing" both surfaces. This in-service micro-polishing smooths the bearing surfaces better than the manufacturing polishing process (shown in Figure 7-31 under 1500 magnification). Smoother bearing surfaces that mate properly increase the available load carrying area, effectively reducing the unit pressure load. Reduced loads greatly extend bearing life.

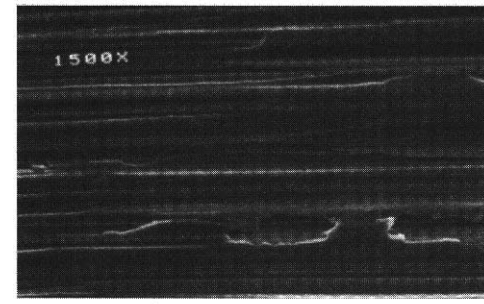
Molecular Composition Is Superior

Royal Purple oils are partially blended with large, high molecular weight synthetic oils. These big molecules keep parts from touching during operation, making them much more effective than viscosity in preventing bearing wear. Synthetic oils from this formulator contain molecules in the 1000/5100 molecular weight range and outperform petroleum oils which are in the low 300/600 molecular weight range. At the same viscosity, high molecular weight oils protect bearings better than low molecular weight oils, thereby extending bearing life.

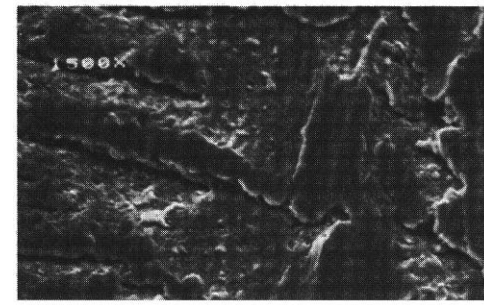
Oil Dryness Is Enhanced

An extensive bearing fatigue life study by Grunberg & Scott shows that an oil contaminated with only 0.002% water (1 drop/quart) reduces bearing fatigue life 48%, regardless of viscosity. Royal Purple oils blended with "dry" hygrophobic synthetic oils (20 to 40 ppm water) protect bearings better than hygroscopic petroleum oils (400 to 6000 ppm water), regardless of viscosity. In service, Royal Purple oils separate rapidly and completely from water to remain dry.

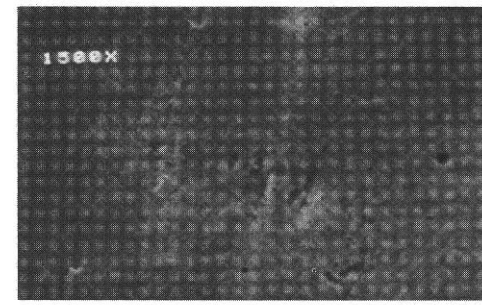
Royal Purple's tough proprietary lubricating film displaces water from bearing surfaces and will not be washed off. Synerlec's™ superior anti-wear, anti-corrosion film protects bearings from wear corrosion—even in very wet environments.



New machined bearing surface appears smooth until magnified 1500 times.



Same bearing surface "galled" using premium competitive synthetic oil (1500 power).



Same bearing surface in same severe service is "micro-polished" by Synerlec™. Surface is much smoother than new surface. (1500 power).

(Scanning Electron Microscope Photos by Det norske Veritas Industry, Inc., Houston Texas)

Figure 7-31. Micro-polishing effect obtained with a high film-strength synthetic lubricant. (Source: Royal Purple, Humble, Texas.)

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Oxidation Stability Is Vastly Superior

Royal Purple oils are many times more oxidation stable than competitive mineral and synthetic oils... 10 times longer in ASTM tests and up to 20 times longer in field service with no break-down. When oils begin to oxidize they lose lubricity and leave harmful lacquer, varnish, carbon, and sludge deposits in equipment that can interfere with efficient operation of bearings and equipment. Superior synthetic lubricants continue to perform like new, leaving no oxidation deposits, long after other oils have completely gelled. Royal Purple lubricants are formulated to perform in the real world where operating temperatures and oil drain intervals are neither timely nor consistent.

Summary

Even the best engineers can not design equipment to meet every conceivable operating condition users devise for their equipment. Bearings fail when subjected to stresses that exceed the ability of the lubricant to protect the bearing surfaces.

In 1980, one of the world's largest ethylene plants converted their 17 large oil-mist lubrication systems from a specially formulated mineral oil to a synthetic oil and found the yearly incremental cost of synthetic lube could be justified if only two pump repairs were avoided. This plant has been successfully operating the oil mist systems ever since.

In a 1982 survey of experience with synthetic oils in refinery equipment, the researchers demonstrated that synthetic lubricants provided increased drain intervals, reduced maintenance, extended component life, and energy savings in a variety of production equipment. These evaluations also established the economic savings attainable through improved overall performance, even though the synthetic lubricant is more expensive than its mineral oil counterpart.

Finally, some synthetic lubricants, notably the ones with formulations based on PAO's and diesters, provide cost-effective lubrication in all service conditions where environmental concerns are of prime importance. Note, however, that not all formulations using the same base stock provide similar performance (Table 7-9).

Whether a specific oil, mineral or synthetic actually excels can only be determined by comparing specific performance properties in actual service. Our advice to the maintenance professional is to determine the performance requirements needed by specific equipment.

Look at the published specifications of various oils and determine their relative merits for the intended service, then monitor the field performance to confirm your expectations. Table 7-10 represents one set of specifications. Make it your goal to compare these data against data furnished by other experienced suppliers!

Bibliography

1. Halliday, Kenneth R.; "Why, When and How to Use Synthetic Lubricants." Selco, Fort Worth, Texas, 1977.
2. Morrison, F.F., Zielinski, James R., "Effects of Synthetic Industrial Fluids on Ball Bearing Performance," ASME Paper 80-Pet-3, presented in New Orleans, Louisiana, Feb. 1980
3. Zielinski, James, and Perrault, Cary E.; "Survey of Commercial Experience With Diester-Based Synthetic Lubricants in Refinery Equipment," NPRA Paper AM-83-20, presented at the 1983 Annual Meeting of the National Petroleum Refiners Asso., San Francisco, March 20-22, 1983.
4. Douglas, Patrick J.; "An Environmental Case for Synthetic Lubricants," *Lubrication Engineering*, September, 1992, pp. 696-700.

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Table 7-9. Although formulated from the same or similar base stocks, laboratory tests and field experience may show performance differences. Synthetic "Y" excels in this comparison.

Performance of Four Synthetic Air Compressor Lubricants										
ASTM #	Test	W		X		Y		Z		Comments
D445	Viscosity @ 100°C (cs)	72.2		75.8		70.6		68.2		
D97	Pour point, °F	-40		-20		-40		-40		
D189	Residue (Conradson) %wt.	0.01		0.02		0.05		0.01		
D130	CU Strip Corrosion (2 hr @ 212°F)	1		1		1		1		All oils showed good corrosion protection.
D665	Rust test @60°C, fresh water	Pass		Pass		Pass		Pass		
	Dry air oxidation, 312 hours @ 250°F, % increase in viscosity	5.1%		7.2%		4.0%		5.1%		If oil goes over 6% it fails. Y should have the longest life in compressor service.
D1401	Demulsibility @ 130°F, 1500 rpm, oil/water/emulsion in minutes	35-35-10 60 minutes		36-36-8 60 minutes		40-40-0 10 minutes		39-39-2 30 minutes		W and X failed. Y had best water separation, so air/oil separator and filters operate longer and more efficiently
D2783	4-Ball EP test (film strength) Weld load, kg. Load Wear Index, kg.	 160 31.3		 160 24.9		 315 66.75		 160 31.4		Y has a significantly greater load bearing oil film to protect loaded bearing surfaces.
D892	Foam test	Foam volume, ml		Foam volume, ml		Foam volume, ml		Foam volume, ml		All oils passed this test.
		5 min	10 min	5 min	10 min	5 min	10 min	5 min	10 min	
	Sequence I	5	0	30	0	30	0	0	0	
	Sequence II	50	0	5	0	20	0	20	0	
	Sequence III	0	0	20	0	20	0	0	0	
D2782	Timken O.K. Load test Load lbs. Scar diameter, mm	 20 weld		 15 weld		 100+ 2.8		 15 weld		Developed by the Timken Company to see how different oils protect loaded bearings. Y shows the greatest film strength. This should particularly improve thrust bearing life.

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Table 7-10. Typical lubricants selected for spur and bevel gears.

Selection criteria	Product name	Base oil / thickener	Service temperature range* (°C) ≈	ISO VG DIN 51 519	Density at 20°C (g/ml) DIN 51757 ≈	Kinematic viscosity DIN 51561, (mm²/s) at ≈ 20 °C	40 °C	100 °C	Viscosity index DIN ISO 2909 (VI)	Pour point DIN ISO 3016 (°C) ≈	Flash point DIN ISO 2592 (°C) ≈	Notes
Synthetic gear oils for high loads and temperatures between -40 and 140 °C	Klübersynth GEM 4-150	Synthetic hydrocarbon oil	-40 to 140	150	0.86	422	150	19	> 140	< -45	> 200	Miscible with mineral hydrocarbon oils; oil change intervals three times as long. Scuffing load stage > 12 in the special FZG test A/16.6/140
	Klübersynth GEM 4-220	Synthetic hydrocarbon oil	-40 to 140	220	0.86	627	220	26	> 150	< -40	> 200	
Synthetic gear oils for high loads and high temperatures up to 160 °C	Klübersynth GH 6-150	Polyglycol oil	-35 to 160	150	1.05	400	150	28	> 210	< -35	> 300	Not miscible with mineral hydrocarbon oils; check compatibility with sealing materials and paint coatings. Scuffing load stage > 12 in the special FZG test A/16.6/140
	Klübersynth GH 6-220	Polyglycol oil	-30 to 160	220	1.05	630	220	41	> 220	< -30	> 300	
Synthetic gear oils for extreme loads and hypoid gears	SYNTHESO D 150 EP	Polyglycol oil	-35 to 100	150	1.05	400	150	28	> 210	< -35	> 200	Not miscible with mineral hydrocarbon oils; check compatibility with sealing materials and paint coatings. Passed FZG test L-42
	SYNTHESO D 220 EP	Polyglycol oil	-30 to 100	220	1.05	550	220	38	> 210	< -35	> 200	
Gear oil for the food-processing industry	Klüberoil 4 UH 1-150	Synthetic hydrocarbon oil	-35 to 110	150	0.85	425	150	22	> 160	-35	> 200	Scuffing load stage 12 in the FZG test A/8.3/90, DIN 51345 Pt 2. USDA-H1 authorization
	Klüberoil 4 UH 1-220	Synthetic hydrocarbon oil	-30 to 110	220	0.85	670	220	33	> 170	-35	> 200	

Selection criteria	Product name	Base oil / thickener	Service temperature range* (°C) ≈	Density at 20°C (g/cm^3) DIN 51757 ≈	Base oil viscosity DIN 51561 (mm^2/s) ≈ 40°C	100°C	Colour	Drop point DIN ISO 2176 (°C)	Speed factor ($n \cdot d_m$) $mm \cdot min^{-1}$ ≈	Worked penetration DIN ISO 2137 (0.1 mm)	Consistency NLGI grade DIN 51 818	Apparent viscosity, KL viscosity grade	Notes
Fluid gear grease for high loads	MICROLUBE GB 00	Min. hydrocarbon oil/silic.	0 to 100	0.9	600	38	reddish-brown	> 200	-	430 to 475	-	EL	Scuffing load stage >12 in the special FZG test A/2.76/5
Fluid synthetic gear grease for high loads, long-term and lifetime lubrication	Klübersynth GE 46-1200	Polyalkylene glycol / Li	-50 to 120	0.99	120	20	brown	> 160	-	400 to 430	00	EL	Scuffing load >12 in the FZG test A/8.3/90, DIN 51354 Pt 2
Fluid gear grease for the food-processing industry	Klübersynth UH 1 - 14 - 1600	Synthetic hydrocarbon oil Al compl. soap	-60 to 120	0.85	160	21	transparent	> 220	500000	400 to 430	00	EL	Scuffing load stage 12 in the special FZG test A/2.76/50. USDA-H1 authorization

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